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City of Watervliet Microgrid Feasibility Study

Microgrid Project Results and Final Written Documentation

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Abstract

Together with the City of Watervliet (Watervliet), Booz Allen Hamilton has completed the feasibility study for a proposed microgrid. This study summarizes the findings and recommendations, results, lessons learned, and benefits of the proposed microgrid. The Project Team has determined the project is feasible, though not without challenges. The commercial and financial viability of the project have been analyzed and detailed in this document. The Watervliet microgrid project faces the challenge of high capital costs, but it benefits from an advantageous mix of generation and loads. A new 450 kilowatt (kW) natural gas reciprocating generator, a new 100 kW solar photovoltaic (PV) array, and two existing 30 kW solar PV arrays will provide reliable, low-emission electricity to customers while providing a proof of concept for a community microgrid in investor-owned utility (IOU) territory. Many of the takeaways of the feasibility study may be generalized across the spectrum of NY Prize and community microgrids.

Keywords: NY Prize, NYSERDA, distributed energy generation, energy resilience, clean energy, DER, Watervliet

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Acronyms and Abbreviations

AC	Alternating Current
AMI	Advanced Metering Infrastructure
ATS	Automatic Transfer Switch
BCA	Benefit Cost Analysis
BEMS	Building Energy Management Systems
BTU	British thermal unit
CAIDI	Customer Average Interruption Duration Index
CHP	Combined Heat and Power
DADRP	Day Ahead Demand Response Program
DC	Direct Current
DER	Distributed Energy Resources
DNP3	Distributed Network Protocol
DPW	Department of Public Works
DR	Demand Response
DSP	Distributed System Platform
EDRP	Emergency Demand Response Program
EE	Energy Efficiency
EMS	Energy Management System
EPA	Environmental Protection Agency
GHG	Greenhouse Gas
Hz	Hertz
ICCP	Inter-Control Center Communications Protocol
IEc	Industrial Economics
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronics Engineers
IOU	Investor-Owned Utility
ISM	Industrial Scientific and Medical
IT	Information Technology
ITC	Investment Tax Credit
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt hour
LAN	Local Area Network
LBMP	Location-Based Marginal Price
LED	Light-Emitting Diode
Mcf	One Thousand Cubic Feet of Natural Gas
MCS	Microgrid Control System
MHz	Megahertz
MMBTU	One Million British Thermal Units
$MMTCO_2e$	Million Metric Tons CO_2 Equivalent
$MTCO_2e$	Metric Tons CO_2 Equivalent
MW	Megawatt
MWh	Megawatt-hour

NYISO	New York Independent System Operator
NYPSC	New York Public Service Commission
NYS DEC	New York State Department of Environmental Conservation
NYSERDA	New York State Energy Research and Development Authority
O&M	Operation and Maintenance
OPC	Open Platform Communication or OLE (Object Link Embedded) Process Control
OPF	Optimal Power Flow
PCC	Point of Common Coupling
PLC	Programmable Logic Controller
PPA	Power Purchase Agreement
PV	Photovoltaic
QF	Qualifying Facility
RAID	Redundant Array of Independent Disks
REV	Reforming the Energy Vision
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SCOPF	Security Constrained Optimal Power Flow
SOA	Service Oriented Architecture
SOW	Statement of Work
TCP/IP	Transmission Control Protocol/Internet Protocol
T&D	Transmission and Distribution
VAC	Volt Alternating Current

Executive Summary

Booz Allen Hamilton was awarded a contract by the New York State Energy Research and Development Authority (NYSERDA) through its New York Prize initiative to conduct a feasibility study of a community microgrid concept in the City of Watervliet. This deliverable presents the findings and recommendations from the previous four tasks, discusses the results and lessons learned from the project, and lays out the environmental and economic benefits for the project. The design demonstrates that the City can improve energy resilience with intentional and emergency island mode capabilities and comply with the greater New York REV (Reforming the Energy Vision) program by constructing 550 kW of clean energy generation capability. The study concludes that the technical design is feasible, however it is financially infeasible as a standalone project.

The Watervliet microgrid project will tie together three critical facilities (per NYSERDA's definition), five other important facilities, and two groups of residential facilities into a community microgrid. Table ES-1 lists all the facilities under consideration for the microgrid concept at this time, and Figure ES- 1 shows their locations in the City of Watervliet.

Table ES- 1. Prospective Microgrid Facilities

Table lists the facilities in the City of Watervliet's proposed microgrid, including their classifications as public, health, or school. The table also denotes critical and important facilities.

Map Label	Property	Classification
F1	Police Station/City Hall	Public*
F2	Fire Station	Public*
F3	Memorial Recreation Center	Public**
F4	Senior Citizen Center/Public Library	Public*
F5	Civic Center	Public**
F6	Public Works Department	Public**
F7	Hudson Shores Plaza	Residential**
F8	United Methodist Church	Community**
F9	Residential Group #1	Residential**
F10	Residential Group #2	Residential**
		* Critical Facility ** Important Facility

In order to meet the energy needs of these critical and important facilities, the microgrid system will incorporate the following existing and proposed generation assets outlined in Table ES-2Table ES-2, below.

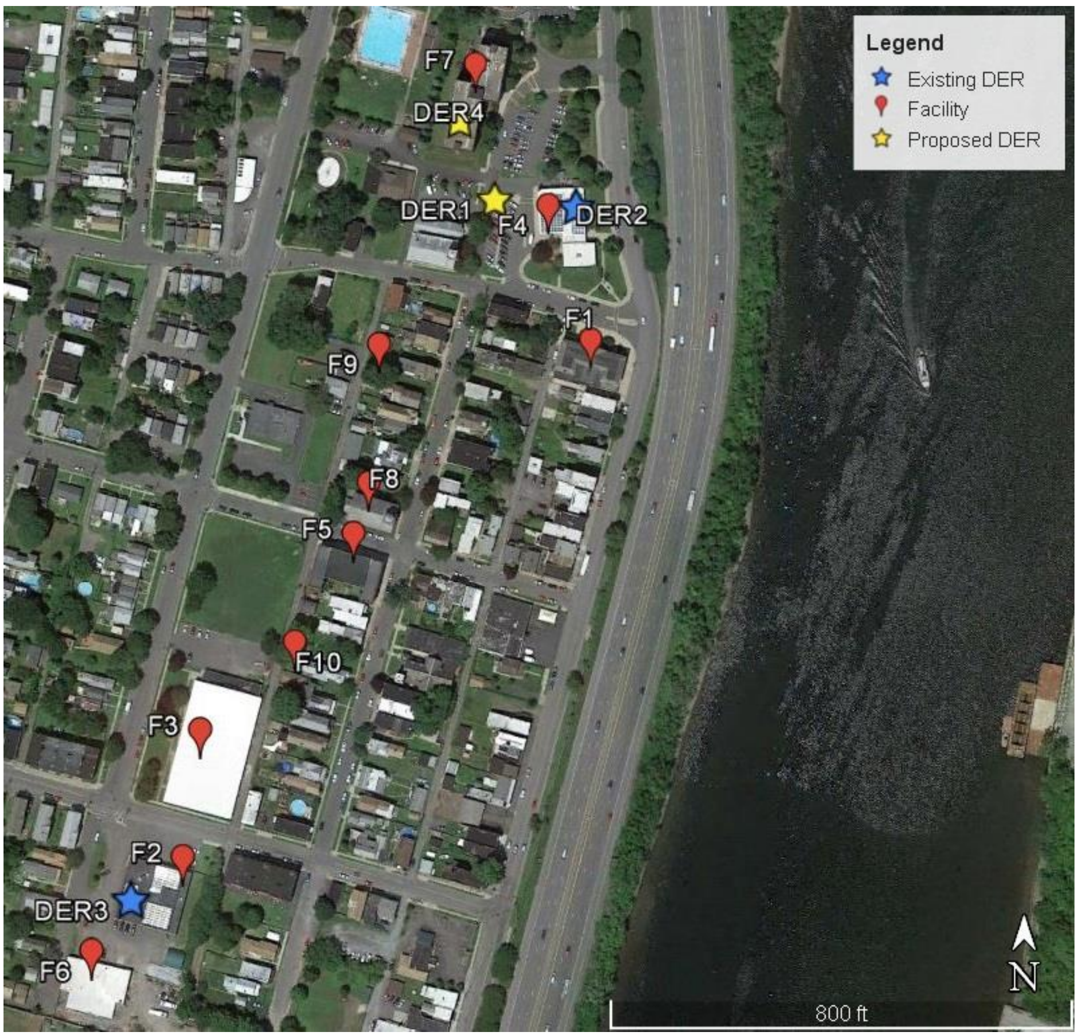
Table ES-2. Watervliet Generation Assets

Table lists the DERs that will be included in the Watervliet microgrid, including their address, fuel source, and nameplate capacity. The table also provides their label for Figure ES-1.

Map Label	Description	Fuel	Capacity (kW)	Address
DER1	**Proposed Reciprocating Generator (Senior Center/Public Library)**	Natural Gas	450	1501 Broadway
DER2	**Existing Rooftop Solar (Senior Center/Public Library)**	Sun Light	30	1501 Broadway
DER3	**Existing Rooftop Solar (Fire Station)**	Sun Light	30	116 13th St
DER4	**Proposed Rooftop Solar (Hudson Shores Plaza)**	Sun Light	100	1545 Broadway

Figure ES- 1. Schematic of Microgrid with Facilities and DERs

Figure shows the proposed microgrid and the locations of the facilities and DERs in the Watervliet microgrid. Existing DERs are marked as blue stars and new/proposed DERs are marked as yellow stars. Facilities are marked as red points.



The proposed DERs will typically have adequate capacity to supply all of the microgrid facilities in Table ES-1 with electricity in island mode. When the solar arrays are operating close to their maximum production points, the microgrid's generation capacity will approach 610 kW, with a guaranteed 450 kW from the reciprocating generator. Aggregate demand from microgrid facilities averaged 314 kW and never exceeded 673 kW in 2014.[1] The backup power supplied by the microgrid will ensure essential services remain accessible during long-term grid outages, providing relief for residents in and around the City of Watervliet. With the addition of these generation assets, the City could experience reduced emissions during peak demand events and could benefit from a more resilient and redundant energy supply to critical services.

The proposal envisions an ownership model wherein the local utility, National Grid, under a waiver from the New York Public Service Commission (NYPSC), owns the new generation and control infrastructure. The Project Team believes this ownership model offers the greatest benefits and flexibility to the utility and customer base within the Town. Given the fairly small generation assets proposed, the Project Team is confident utility ownership of generation in this project does not run contrary to the general prohibition on utility ownership of utility-scale generation assets.

The proposed distributed energy resources (DERs) will generate revenues from electricity sales. Annual revenues will exceed the annual costs of production, but the high cost of the infrastructure relative to the size of generation may prevent the project from independently achieving commercial viability. With funding from NYSERDA, the community microgrid in the City of Watervliet is feasible and will help maintain critical services to the community and extend resilient electrical service to a low and moderate income community.

The microgrid will incur initial capital costs of $1.4 million as well as yearly operation, maintenance, and fuel costs totaling $225,000 per year. Design costs will be approximately $500,000. Overall revenue streams from the project are estimated at $250,000 per year and will be captured primarily through the sale of electricity during grid-connected mode. The proposed microgrid's commercial feasibility depends on NY Prize Phase III funding and additional operating subsidies. On an annual basis, costs will exceed revenues, and when capital expenditures are included, the project does not cover its total costs.

The Watervliet microgrid concept, with new reliable and renewable generation and the integration of existing energy resources, provides the City with an energy resilience solution that is technically sound and, with the NY Prize, financially viable. The ability to island three critical facilities (per NYSERDA's definition), five other important facilities, and two groups of residential facilities is a significant addition to the resilience of the City in times of emergency and extended grid outages.

[1] This estimate was calculated by summing each facility's peak demand from 2014. The estimate therefore assumes that all facilities reached peak demand at the same time, which is unlikely. The true peak demand was almost certainly less than 673 kW, but the Project Team was unable to obtain synchronized real-time load data for all included facilities.

1. Introduction

The City of Watervliet is seeking to develop a community microgrid to improve energy service resilience, accommodate distributed energy resources and reduce greenhouse gas (GHG) emissions. Working with the City of Watervliet and National Grid, a team from Booz Allen Hamilton (hereafter Booz Allen or the Project Team) designed a preliminary microgrid concept that will connect three critical facilities, five other important facilities, and two groups of residential facilities with two new generation assets and two existing solar PV arrays. The design proposes a new 450 kW natural gas-fired reciprocating generator located at the Senior Center / Public Library and a new 100 kW solar PV rooftop array located at Hudson Shores Plaza. The design also incorporates two existing 30 kW solar PV arrays located at the Fire Station and the Senior Center / Public Library. In this document, the Project Team discusses the observations, findings, and recommendations from the entirety of the analysis. Within the document, Booz Allen also explores avenues for further development, discusses project results, and shares lessons learned regarding configuration, capabilities, environmental and economic benefits, and implementation scenarios.

The City of Watervliet and its residents seek to improve the resilience of energy service and lower their environmental footprint. More specifically, the City faces several challenges that could be mitigated with a community microgrid:

- Some critical services in Watervliet do not have backup generation. These facilities are therefore vulnerable to prolonged interruptions or outages in grid-supplied power.
- Extreme weather events and seasonal weather changes cause energy price volatility, and consumers are seldom able to respond to these price signals. There are no clear incentives to shift load or self-generate in response to price changes. Other than reducing consumption, ratepayers have few options when prices soar.
- Electricity service in the region has occasionally been interrupted by extreme weather events such as winter storms, rainstorms, and heatwaves. A microgrid could provide needed resiliency to critical services in the City.
- In order to improve its energy profile and reduce its carbon footprint, the community prefers low-emission options for distributed energy resources. An integrated microgrid adds value to advanced distributed energy resource technologies, increasing the viability of the proposed reciprocating generator and making energy from the solar arrays available even in grid outage scenarios.

2. Microgrid Capabilities and Technical Design and Configuration

This section provides a combined overview of the criteria assessed in Task 1 - Microgrid Capabilities and Task 2 – Technical Design and Configuration. The tasks were combined and address all of the criteria in the following order: microgrid capabilities, DER characterization, load characterization, proposed microgrid infrastructure and operations, electric and thermal infrastructure characterization, microgrid building and controls, and IT and telecommunications infrastructure.

2.1 Project Purpose and Need

The Watervliet microgrid will improve the resilience of the local electricity grid in emergency outage situations, accommodate distributed energy generation, and reduce reliance on high emissions peaking assets during peak demand events. The City of Watervliet experiences the usual range of extreme weather that faces the region, including torrential rain, snow, wind, and flooding, all of which may impact the larger grid's ability to safely, reliably, and efficiently deliver electricity to customers. Avoiding outages has significant monetary value to the connected facilities. Interruptions to the power supply can derail operations, cause damage to machinery, and render direct health/safety equipment ineffective. Moreover, the footprint of the microgrid encompasses a predominately low and moderate income group of residential buildings, and expanding energy resilience within these communities is a paramount goal of the State. Watervliet has several shelters, municipal facilities, and residences clustered within 0.5 miles of each other and on the same electrical circuit. This proximity encourages the construction of a microgrid because several important facilities can be incorporated into the design without the need for extensive new distribution infrastructure.

The Project Team estimates the microgrid's main DERs will generate an instantaneous average output of approximately 400 kW of electricity throughout the year.[2] Although Watervliet is not currently considered a critical congestion point on the New York State grid, this generation capacity will reduce the amount of power that must be transmitted to the City from the larger grid, which may result in lower congestion costs to National Grid in the surrounding area. The project could serve as a model for the critical congestion points in the area, providing data on how distributed energy resources affect required transmission capacity for NYSERDA and the NYISO. Coupled with other distributed energy resource projects in the area or elsewhere, in the form of other NY Prize microgrids or other projects, the aggregate reduction of load on the transmission system could be material.

The City provides an opportunity to examine the prospects of a replicable, modular microgrid solution in IOU territory. New York State has experienced severe longstanding congestion at critical points on the transmission system linking upstate and downstate New York, some of which could be eliminated by investing in distributed energy generation and microgrids with intentional island mode capability. The project could serve as a model for the critical congestion points in the area, providing data on how distributed energy resources affect required transmission capacity for NYSERDA and NYISO.

[2] Natural gas capacity factor: 85% (EPA; http://www3.epa.gov/chp/documents/faq.pdf); Solar PV capacity factor: 14% (NREL PV Watts Calculator).

The proposed natural gas-fired DER will provide essential reliability to the Watervliet microgrid. Natural gas emits significantly less greenhouse gases per unit of energy than diesel or fuel oil, the typical fuel sources for backup generators, and is currently more cost-effective than combined solar and storage systems. The reciprocating generator will improve energy resiliency in Watervliet and will lessen the strain on the local electricity distribution network by reducing the need for power imports during peak demand events. The proposed solar array will help offset emissions from the reciprocating generator and represents a significant investment in local renewable energy generation.

2.2 Microgrid Required and Preferred Capabilities (Sub Tasks 1.1 and 1.2)

The NYSERDA statement of work (SOW) 63935 outlines 15 required capabilities and 18 preferred capabilities each NY Prize microgrid feasibility study must address. Table 1 summarizes required and preferred capabilities met by the proposed microgrid design in greater detail.

Table 1. Microgrid Capabilities Matrix

Table lists NYSERDA's required and preferred capabilities and annotations of whether or not the Watervliet microgrid will meet these criteria.

Capability	Required/ Preferred	Microgrid will meet (Y/N)
Serves more than one, physically separated critical facilities	Required	Y
Primary generation source not totally diesel fueled	Required	Y
Provides on-site power in both grid-connected and islanded mode	Required	Y
Intentional islanding	Required	Y[3]
Seamless and automatic grid separation/restoration	Required	Y
Meets state and utility interconnection standards	Required	Y
Capable of 24/7 operation	Required	Y
Operator capable of two-way communication and control with local utility	Required	Y
Load following while maintaining the voltage and frequency when running in parallel to grid	Required	Y
Load following and maintaining system voltage when islanded	Required	Y
Diverse customer mix (residential, commercial, industrial)	Required	Y
Resiliency to wind, rain, and snow storms	Required	Y
Provide black-start capability	Required	Y
Energy efficiency upgrades	Required	Y
Cyber secure and resilient to cyber intrusion/disruption	Required	Y
Microgrid logic controllers	Preferred*	Y
Smart grid technologies	Preferred*	Y
Smart meters	Preferred	N
Distribution automation	Preferred*	Y
Energy storage	Preferred	N
Active network control system	Preferred*	Y
Demand response	Preferred	Y[4]
Clean power sources integrated	Preferred	Y
Optimal power flow (OPF) (economic dispatch of generators)	Preferred	Y
Storage optimization	Preferred	N
PV observability, controllability, and forecasting	Preferred	Y
Coordination of protection settings	Preferred	Y
Selling energy and ancillary services	Preferred	N[5]
Data logging features	Preferred	Y
Leverage private capital	Preferred	Y
Accounting for needs and constraints of all stakeholders	Preferred	Y
Demonstrate tangible community benefit	Preferred	Y
Identify synergies with Reforming the Energy Vision	Preferred	Y
* capability is characterized as preferred by NYSERDA but is a required component in this design		

The sections that follow address how the microgrid will meet these capabilities in more detail.

[3] While the system will be technically capable of intentional islanding, doing so would cut power flow to other customers on the included feeders and thus would not be feasible for economic purposes.
[4] The system is technically capable of providing demand response, but it is unclear whether islanding the microgrid will qualify for DR programs (both load and generation assets will be taken offline simultaneously).
[5] Microgrid has the *capability* to sell energy and ancillary services, but may not sell ancillary services in reality.

2.2.1 Serving Multiple, Physically Separated Critical Facilities

The City of Watervliet and the Booz Allen Team, in cooperation with National Grid, have identified eight facilities and two groups of residential units that will be connected to the microgrid. Three of the included facilities will provide critical services (as defined by NYSERDA) to the community in the case of an outage. See Table 2 for a full list of prospective facilities to be tied into the microgrid.

Table 3. City of Watervliet Critical and Important Facilities

Table lists critical and important facilities, their addresses, and their classifications as critical or important.

Name of Facility	Address	Classification (Critical, Important)
Police Station/City Hall	2 15th St	Critical
Fire Station	116 13th St	Critical
Memorial Recreation Center	Corner of 13th Street & 2nd Avenue	Important
Senior Citizen Center/Public Library	1501 Broadway	Critical
Civic Center	14th St.	Important
Public Works Department	1200 2nd Avenue	Important
Hudson Shores Plaza	1545 Broadway	Important
United Methodist Church	1401 1st Ave	Important
Residential Group #1	1409-1433 1st Ave	Important
Residential Group #2	1307-1335 1st Ave	Important

The proposed microgrid footprint occupies approximately 20 acres in Watervliet. A new medium-voltage express line will connect loads from different feeders. Facilities and microgrid equipment will communicate over National Grid's WAN (utilizing the existing IT fiber optic backbone). Utilizing industry standard protocols, such as Distributed Network Protocol (DNP3), Open Platform Communication (OPC), Modbus, 61850, and Inter-Control Center Communications Protocol (ICCP) (IEC 60870-6) will enable the remote monitoring and control of distributed devices, regardless of manufacturer. The microgrid is designed with flexibility and scalability in order to accommodate future expansion and technologies.

2.2.2 Limited Use of Diesel Fueled Generators

The City of Watervliet has established a preference for natural gas cogeneration plants and solar PV arrays to serve as the primary generators for the community microgrid. The Project Team evaluated potential thermal loads in Watervliet but found that there is insufficient steam demand to merit addition of combined heat and power (CHP) capability to the proposed reciprocating generator.

The Project Team also evaluated the possibility of using solar energy as the primary energy source, but solar arrays do not provide the reliability required in a community microgrid unless they are integrated with battery storage systems or some other form of backup generation. The Team determined that installing a new natural gas reciprocating generator is the most cost effective way to guarantee the microgrid's energy supply in island mode. As a comparatively low-emission, highly reliable fuel, natural gas is an ideal source of energy for a community microgrid.

2.2.3 Local Power in both Grid-Connected and Islanded Mode

The microgrid will provide on-site power in both grid-connected and islanded mode. In island mode, the MCS will optimize on-site generation to maintain stable and reliable power flow. The control system is capable of disconnecting the Hudson Shores Plaza complex in real time if aggregate microgrid demand exceeds available generator capacity, but the design does not include further load-shedding capability.[6] The Hudson Shores Plaza facility represents approximately 69% of the microgrid's load, making further load shedding in island mode unnecessary. In grid-connected mode, the microgrid will optimize the use of available assets to reduce energy costs when possible and export to the National Grid system when economic and technical conditions align.

The proposed generation assets will operate continuously in grid-connected mode, reducing local dependence on grid-supplied power. In island mode, the MCS will deploy available energy from the solar arrays and manage the reciprocating generator's output to meet remaining demand as necessary. If the Hudson Shores Plaza facility must be disconnected, the reciprocating generator will have sufficient capacity to provide electricity to all remaining microgrid facilities in island mode, guaranteeing that facilities will have a reliable source of power regardless of weather or time of day.

2.2.4 Intentional Islanding

The microgrid will intentionally switch to island mode when doing so results in a more stable and reliable environment. Transitions to island mode will comply with New York State standardized interconnection requirements as well as local utility and building codes, which will ensure equipment and personnel safety throughout each phase of the switch.

After receiving a command from the system operator, the MCS will automatically start and parallel off-line generation assets. Once the available power sources are synchronized with the grid (and each other), the system is ready to disconnect from the larger grid, and it will begin by opening the incoming utility line breakers. After completing the transition to island mode, the MCS must maintain system voltage and frequency between acceptable limits and adjust generator output to match aggregate load.

However, when the Watervliet microgrid switches to island mode, it will disconnect all downstream non-microgrid loads that normally receive power from the Maplewood Station 307 feeder. There may be additional National Grid feeders in the area that can bring power to the City—if so, this redundancy could ensure downstream loads do not lose power when the microgrid switches to island mode in a non-outage scenario. If such redundancy exists the system may be able to participate in demand response (DR) programs or beat high electricity

[6] The proposed reciprocating generator will provide rapid responses to fluctuations in system voltage and frequency, so further load-shedding capability is unnecessary for the Watervliet microgrid. The Project Team determined that energizing all loads in the microgrid coverage area (with the exception of the Hudson Shores Plaza complex) is feasible.

prices on the spot market by switching to island mode. Future phases of this study will conduct in-depth analyses on the possibilities of intentionally switching to island mode in non-outage scenarios and whether National Grid would need to build additional lines to ensure redundancy for all affected customers.

2.2.5 Resynchronization to National Grid Power

When operating in island mode, the microgrid will constantly monitor the status of the larger grid and will re-connect when conditions have stabilized. Signals from the MCS will prompt re-connection when monitored operational variables on the larger grid satisfy predetermined conditions. The MCS will be capable of both pre-programmed and manual re-connection using synchronization and protection equipment.

The microgrid design requires an upgrade to the manual switch along the Maplewood Station 307 feeder on Broadway Avenue. The control system will trigger the opening or closing of this breaker as appropriate during system transitions.

2.2.6 Standardized Interconnection

The microgrid design complies with NYPSC interconnection standards. Table 3 outlines the most significant state interconnection standards that apply to this microgrid project. Customers that wish to connect DER projects to the National Grid system must follow the same New York State Standard Interconnection Requirements identified in Table 3.

Table 4. New York State Interconnection Standards[7]

Table outlines New York State interconnection standards by category (common, synchronous generators, induction generators, inverters, and metering) and a description of the standard.

Standard Category	Description
Common	Generator-owner shall provide appropriate protection and control equipment, including a protective device that utilizes an automatic disconnect device to disconnect the generation in the event that the portion of the utility system that serves the generator is de-energized for any reason or for a fault in the generator-owner's system
	The generator-owner's protection and control scheme shall be designed to ensure that the generation remains in operation when the frequency and voltage of the utility system is within the limits specified by the required operating ranges
	The specific design of the protection, control, and grounding schemes will depend on the size and characteristics of the generator-owner's generation, as well as the generator-owner's load level, in addition to the characteristics of the particular portion of the utility's system where the generator-owner is interconnecting
	The generator-owner shall have, as a minimum, an automatic disconnect device(s) sized to meet all applicable local, state, and federal codes and operated by over and under voltage and over and under frequency protection
	The required operating range for the generators shall be from 88% to 110% of nominal voltage magnitude

[7] New York State Public Service Commission. *Standardized Interconnection Requirements and Application Process for New Distributed Generators 2 MW or Less Connected in Parallel with Utility Distribution Systems* (2014). Available from www.dps.ny.gov.

Standard Category	Description
	The required operating range for the generators shall be from 59.3 Hertz (Hz) to 60.5 Hz
Synchronous Generators	Requires synchronizing facilities, including automatic synchronizing equipment or manual synchronizing with relay supervision, voltage regulator, and power factor control
	Sufficient reactive power capability shall be provided by the generator-owner to withstand normal voltage changes on the utility's system
	Voltage regulator must be provided and be capable of maintaining the generator voltage under steady state conditions within plus or minus 1.5% of any set point and within an operating range of plus or minus 5% of the rated voltage of the generator
	Adopt one of the following grounding methods: • Solid grounding • High- or low-resistance grounding • High- or low-reactance grounding • Ground fault neutralizer grounding
Induction Generators	May be connected and brought up to synchronous speed if it can be demonstrated that the initial voltage drop measured at the point of common coupling (PCC) is acceptable based on current inrush limits
Source: NYS Standardized Interconnection Requirements and Application Process, NYS PSC	

2.2.7 24/7 Operation Capability

The project concept envisions a reciprocating natural gas-fired generator as the microgrid's main generation source. The City's existing natural gas supply lines can support 24/7 continuous operation of the reciprocating generator.

2.2.8 Two Way Communication with Local Utility

There is currently no automation system in place which would allow communication between the microgrid operator and the existing electrical distribution network in Watervliet. The new automation solution proposed in this report will serve as a protocol converter to send and receive all data available to the operator over National Grid's WAN using industry standard protocols such as DNP3, OPC, Modbus, 61850, and ICCP (IEC 60870-6).

2.2.9 Voltage and Frequency Synchronization when Connected to the Grid

Microgrid controllers will automatically synchronize the frequency and voltage of the reciprocating generator and 100 kW solar PV array to the larger grid—however, the 30 kW solar arrays are too small to have a significant impact on synchronization and power quality, and thus will not be under microgrid control. Synchronization is key to maintaining a stable power network. The larger grid also requires constant synchronization of energy sources, but its comparatively higher electrical and mechanical inertia filters out most fast dynamics. In contrast, the microgrid will be sensitive to fluctuations in load or generator output. It is therefore crucial to constantly monitor and regulate output from the reciprocating generator and 100 kW solar PV array against aggregate load in real time.

2.2.10 Load Following and Frequency and Voltage Stability when Islanded

The microgrid's control scheme in islanded mode operates in a similar fashion to the larger transmission system. The system maintains frequency by controlling real power generation and regulates voltage by controlling reactive power availability. To the degree that flexible loads are available, the MCS can curtail facility load—only the Hudson Shores Plaza facility will be equipped with the necessary equipment to disconnect from the microgrid in real time.

If generation matches the load plus the system losses (real and reactive), system frequency and voltage should stay within acceptable limits. Other factors, such as network topology and the distribution of generation and loads, can also affect frequency and voltage stability. The Project Team will consider these factors and develop a microgrid design that accounts for them in the next phase of the NY Prize competition. The comparatively small size of the microgrid introduces new, fast, and dynamics-related problems that will be carefully studied during the engineering design phase.

2.2.11 Diverse Customer Mix

Connected facilities have varying impacts on power quality and stability based on load size and economic sector. A microgrid with too many industrial or digital electronics-based loads may be less reliable because these loads can negatively affect power quality and stability. The Watervliet microgrid will primarily serve public facilities (including a fire station, a police station, a public library, and a recreation center) and residential units (including a low-income apartment complex and several individual houses). The approximate load breakdown by sector for the Watervliet microgrid is as follows:[8]

- Public – 25% of load
- Residential – 75% of load

The Hudson Shores Plaza residential complex accounts for approximately 69% of the microgrid's load. Targeted energy efficiency (EE) upgrades could significantly reduce this facility's (and therefore the microgrid's) average electricity demand (see Section 2.2.14 for more details).

2.2.12 Resiliency to Weather Conditions

The City of Watervliet is exposed to the normal range of weather conditions that affects the Northeastern United States. Extreme weather events include, but are not limited to, torrential rain, snow, and wind that could cause falling objects and debris to disrupt electric service and damage equipment and lives. Watervliet has experienced several significant disruptions to power service from extreme weather events and animal damage to infrastructure in the recent past.

By implementing line fault notifications and deploying other sensors, microgrid owners can ensure the network is as resilient as possible to storms and other unforeseen forces of nature. At minimum, the new reciprocating generator (the microgrid's main generation asset) will be constructed inside an enclosure on the Senior Citizen Center/Public Library's land and will therefore be safe from extreme weather. If constructed overhead, the new express line may be exposed to severe weather; however, burying the line underground may represent a crippling

[8] Estimated based on each facility's typical 24 hour load profile from a typical month in 2014.

capital cost. The Team will weigh the benefits and costs of overhead and underground line placement during the next phase of the NY Prize competition.

2.2.13 Black Start Capability

The proposed reciprocating generator will be equipped with black-start capabilities. If the larger National Grid system unexpectedly loses power, the MCS will initiate island mode by orchestrating the predefined black-start sequence. The reciprocating generator will require an auxiliary source of DC power to start multiple times in case of failure. It will ramp up to 60 Hz and prepare to supply each of the microgrid loads in sequence. After the reciprocating generator has established a stable power supply, the MCS will synchronize output from the 100 kW solar PV array and bring it on-line. The 30 kW solar arrays are too small to impact power quality or synchronization, and therefore will operate continuously throughout the black start sequence.

2.2.14 Energy Efficiency Upgrades

Energy efficiency is critical to the overall microgrid concept. The City of Watervliet has developed an ambitious Climate Action Plan to reduce GHG emissions, which includes a 10-year phased performance contract to reduce energy use in municipal buildings. The first phase of this contract included retrofitting the City Hall HVAC and installing Honeywell lighting upgrades, window glaze, and vending misers. The Civic Center recently upgraded the on-site furnace and replaced the roof, and the Recreation Center's roof was recently resealed. The next phases of the EE effort will target other buildings throughout the city.

Several of the targeted EE efforts may qualify for local National Grid or NYSERDA incentives.

Existing Watervliet EE Programs

The Project Team estimates the reduction potential for the included facilities to be approximately 40 kW. The project will leverage existing National Grid EE programs to reduce load at existing facilities and will seek to qualify for NYSERDA funded EE programs.

Applicable EE programs include:

- National Grid Small Business Program: National Grid offers incentives that cover up to 60% of the cost of qualified energy efficient equipment. Available equipment includes lighting upgrades (including light-emitting diode (LED) lights), lighting occupancy sensors, and walk-in cooler efficiency measures. The various municipal buildings in Watervliet may qualify for this program.
- National Grid programs for large businesses: National Grid offers several programs for large businesses, targeting Lighting and Controls, Compressed Air, energy management systems (EMS), vending misers, and hotel occupancy sensors. National Grid provides technical guidance for Lighting and Controls systems, as well as financial incentives that partially offset the cost of high performance lighting.[9] Similar incentives are available

[9] For a list of qualifying lighting upgrades, see: https://www1.nationalgridus.com/files/AddedPDF/POA/EE4735_LightingIncentives_UNY.pdf.

for simple, cost effective changes to existing high-efficiency air compressors and dryers (improvements can often be paid back in as little as one year after counting National Grid incentives).[10] Finally, National Grid can assist commercial, industrial, and municipal customers by assessing the need for a local building energy management system (BEMS) and providing incentives for qualifying facilities.[11] None of the current microgrid facilities will qualify for these programs, but if the microgrid expands to include large businesses in the future (such as the Price Chopper supermarket), these programs could have a major impact on overall microgrid load.

- National Grid Energy*Wise* multifamily program: This program provides incentives for residents and/or property owners in apartments or condominium complexes with 5-50 units. The program includes a free energy evaluation to assess energy usage and EE potential as well as free installation of compact fluorescent lightbulbs (10 per dwelling unit), free installation of low-flow showerheads, faucet aerators, hot water pipe wrap, and tank wrap, a $300 rebate towards refrigerator replacement costs, and free installation of programmable thermostats. The Hudson Shores Plaza building may qualify for this program.
- National Grid High-Efficiency Electric Water Heaters: High-efficiency electric water heaters can reduce water heating costs by as much as 30%, and National Grid offers a $400 rebate for ENERGY STAR-certified electric heat pump water heaters. National Grid also offers a rebate of $0.50 per linear foot of foam pipe insulation on hot water supply lines. All of the Watervliet microgrid facilities may be eligible for this program.
- NYSERDA Commercial Existing Facilities Program: This program offers facilities two options for participation. Under the pre-qualified path, NYSERDA will compensate participating facilities up to $60k for qualifying retrofits or EE upgrades (such as lighting, commercial refrigeration, HVAC, and gas equipment upgrades). Facilities can also apply for custom incentives under the performance-based path (if a facility wishes to participate in this path, it is crucial to involve NYSERDA early in the planning and development process). The various municipal buildings in Watervliet may qualify for this program.

2.2.15 Cyber Security

The microgrid management and control system network data will be fully encrypted when stored or transmitted. Network segmentation by function, network firewalls, and continuous monitoring of data activity will protect the microgrid from cyber intrusion and disruption. Access to the microgrid management and control center will be limited to authorized personnel. Activating and analyzing security logs may provide an additional level of security. The operating system and firewall will be configured to record certain suspicious events, such as failed login attempts.

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[10] For a list of qualifying compressed air upgrades, see: https://www1.nationalgridus.com/files/AddedPDF/POA/EE4740_CAIR_UNY.pdf.

[11] For a list of BEMS incentives, see: https://www1.nationalgridus.com/files/AddedPDF/POA/EE4761_EMS_UNY.pdf.

Because the logic controllers, or IEDs, will be located at or near loads, the distributed equipment will take the IT system to the "edge" of the network, where it may be more vulnerable to hackers. A practical tool to prevent unauthorized access into the IT network is a program called sticky media access control (MAC). Every network attached device has a MAC interface that is unique to it and never changes. The sticky MAC program monitors the unique address of the device and its designated network port, and if the device is ever disconnected, the program disables that port and prevents an unauthorized device from entering the IT system. The Project Team recommends implementing sticky MAC as a practical, cost effective cyber security measure.

2.2.16 Use of Microgrid Logic Controllers

Microprocessor-based IEDs serving as microgrid logic controllers are described below in Section 2.7.1. The role of the IEDs is to provide monitoring and control capabilities of the object being controlled. The Project Team believes this is a required capability for this proposed microgrid.

2.2.17 Smart Grid Technologies

The microgrid will offer a distributed network architecture allowing smart grid technologies to connect to the grid via multiple protocols including DNP3, OPC, Modbus, 61850, ICCP (IEC 60870-6), and more as required. The Project Team believes this is a required capability for this proposed microgrid.

2.2.18 Smart Meters

The City of Watervliet does not have smart meters installed throughout its coverage area. Smart meters are not required for the Watervliet microgrid because the control sequence is performed at the feeder and facility-level.

2.2.19 Distribution Automation

The automation solution outlined in this study includes IEDs that are distributed at or near individual loads. Their role is to control the load and communicate monitored variables to the control system servers for processing, viewing, and data logging. IEDs can operate based on automated signals from the MCS or pre-programmed independent logic in case of a loss of communication with the MCS. The Project Team believes this is a required capability for the proposed microgrid.

2.2.20 Energy Storage

The Project Team's analysis of battery storage technologies found their cost to be prohibitively high. Despite this, the MCS will be equipped with the capability to fully utilize and optimize the storage resources—including charging and discharging cycles for peak demand shaving—in case the City reevaluates its options in the future. The price of battery storage technology is constantly decreasing, and by "stacking" different uses of energy storage (i.e., microgrid resiliency, frequency regulation, and PV integration), microgrid owners may soon be able to achieve a competitive levelized cost of storage.[12]

[12] Lazard's Levelized Cost of Storage Analysis, Version 1.0.

2.2.21 Active Network Control System

The microgrid will be under continuous and close monitoring and control when it operates in either grid-connected or islanded mode. Both monitoring and control will be decomposed into central (slow) and distributed (fast) components. A fast and reliable communication network is needed for such a hierarchical approach to be successful. All controllable components on the microgrid will communicate bi-directionally with the MCS via MODBUS, OPC, DNP3 TCP/IP, or other protocols as required. The communication infrastructure will be based on National Grid's IT network partitioned using gigabit Ethernet switches.

2.2.22 Demand Response

The Watervliet microgrid will not intentionally switch to island mode to participate in demand response programs because doing so will disconnect all downstream loads on the Maplewood Station 307 feeder. The microgrid's participation in DR programs will therefore be limited to curtailing flexible loads, increasing the reciprocating generator's output, and possibly bringing non-connected local natural gas generators, such as the 30 kW generators, on-line. The microgrid could serve as a virtual load aggregator, bringing the total load reduction above the minimum threshold of 100 kW, and reap some share of the profits for doing so. However, the generation assets in the proposed microgrid are sized to approximately match the City's peak demand, so the microgrid cannot guarantee that capacity from the reciprocating generator will always be available. Participation in DR programs will likely be limited to voluntary participation when capacity is available.

National Grid offers two DR programs: the Emergency Demand Response Program (EDRP) and Day Ahead Demand Response Program (DADRP). National Grid deploys the EDRP when the NYISO declares a system emergency. Participants must be able to curtail at least 100 kW of load one hour after notification—this load reduction can be accomplished by reducing energy usage or deploying on-site generation, but owners of on-site generators must complete an additional application form. The NYISO pays National Grid the greater of $500/megawatt hour (MWh) reduced or the real time Location Based Marginal Price (LBMP) during the event, and National Grid passes on 90% of this payment to participating customers

The DADRP allows customers to bid reduced loads for the following day when prices are high. Customers are reimbursed based on the day ahead LBMP and are penalized for non-compliance with submitted bids. Load reductions from on-site generation are ineligible for this program. It is therefore unlikely that the microgrid will participate in this program.

The microgrid may be eligible for participation in the NYISO Special Case Resources (SCR) program. Participants in this program receive a monthly capacity payment and are required to reduce load when signaled to do so by the NYISO. Participation in the SCR program prevents participation in the National Grid EDRP because the same demand response events are declared for both programs.

Participation in the National Grid EDRP and DADRP will not produce significant revenue streams for the Watervliet microgrid. Load reduction is limited to available capacity from the reciprocating generator, which must always be available to produce energy for the microgrid in case of emergency. The microgrid should therefore avoid DR programs that penalize participants for non-compliance.

2.2.23 Clean Power Sources Integration

The proposed energy sources, natural gas and solar energy, will provide the microgrid with reliable and relatively low-emission electricity. In the future it may be possible to expand the footprint or generation assets to include additional clean power sources. At that time, the Project Team will consider biomass, battery storage, and fuel cells. More detailed methods to capture and convert energy by electric generators or inverters will be explored at a later time.

2.2.24 Optimal Power Flow

As recommended by National Grid, the proposed community microgrid is fairly small, with an average load of only 314 kW. The Project Team expects that microgrid owners will negotiate a long-term power purchase agreement (PPA) with National Grid in which proposed DERs are compensated for exporting energy to the larger grid in grid-connected mode. The structure of this power purchase agreement will influence each generator's level of operation throughout the year. The MCS will optimize the output of generation sources at the lowest cost in a unique approach that includes fuel cost, maintenance, and energy cost as part of security constrained optimal power flow (SCOPF).

2.2.25 Storage Optimization

Pending a decrease in unit pricing, the microgrid could potentially expand in the future to include energy storage, in that event, the storage system will require intelligent controls to work in unison with the microgrid controls. In this event, the MCS would fully utilize and optimize the storage resources by managing the charge and discharge of storage systems. Possible uses for storage include reducing peak demand, participating in NYISO frequency regulation markets, shifting solar PV output to match aggregate load, and increasing system reliability by providing an energy bank.

2.2.26 PV Monitoring, Control, and Forecasting

The microgrid's PV inverters will usually operate at their maximum power point (MPP) in order to maximize the power production of the overall system, and because there is no associated O&M cost. As with many other renewable energy sources, power output depends on weather and time of day. Because the 30 kW PV arrays are too small to have a significant effect on the stability of the power system, they will not be outfitted with generation controllers or switchgear.

The MCS includes high resolution solar forecasting. Solar forecasting can increase the value of integrated PV and storage systems by intelligently deploying storage to smooth the natural spikes in the daily PV output curve. While this functionality could be useful in the future should the microgrid have energy storage added, the current design does not include battery storage or the ability to regulate output from the solar PV arrays.

2.2.27 Protection Coordination

Microgrid protection strategies can be quite complex depending on the network topology and distribution of load and generation. The existing protection scheme assumes unidirectional power flow of a certain magnitude. The microgrid introduces the possibility of bidirectional power flow in both grid-connected and islanded mode, which may complicate the necessary protection strategy. In later phases of this study, the microgrid designer will perform protection studies that account for possible bidirectional power flows and low fault currents, which can occur when the microgrid is operating in island mode.

2.2.28 Selling Energy and Ancillary Services

It is unclear whether the microgrid will be permitted to back-feed through Watervliet's main substation into the broader National Grid transmission system. If allowed, the microgrid will sell excess energy from the solar array and reciprocating generator to National Grid.

The NYISO ancillary service markets with the greatest returns (such as the frequency regulation market) require participants to bid at least 1 megawatt (MW) of capacity. The microgrid's generation assets have an aggregate capacity of 610 kW, so participation in these ancillary service markets will not be possible. Other ancillary service markets, such as spinning and non-spinning reserves, do not provide competitive payments to small scale generators such as the microgrid's 450 kW reciprocating generator. The Project Team has concluded the proposed microgrid will not participate in NYISO ancillary service markets.

2.2.29 Data Logging Features

The microgrid control center includes a Historian Database to maintain real-time data logs. The Historian Database can also display historical trends in system conditions and process variables.

2.2.30 Leverage Private Capital

The microgrid project will seek to leverage private capital where possible in order to develop components of the microgrid. The Project Team is actively developing relationships with investors and project developers that have expressed interest in NY Prize. As the project concept matures, the Project Team will continue to engage these groups to better understand how private capital can be leveraged for this specific project. The Project Team currently envisions continuous operation of all included generators and sale of energy under a custom long-term power purchase agreement with National Grid. More detail is provided in Section 3.5.1.

2.2.31 Accounting for Needs and Constraints of Stakeholders

Developing the best possible value proposition for the community, utility, local industry, and other community stakeholders is at the center of this feasibility study. The Project Team has engaged with all involved parties to understand their specific needs and constraints. Additional detail about costs and benefits by stakeholder group can be found in Section 3.2.3.

2.2.32 Demonstrate Tangible Community Benefit

The project's success and acceptance rely on its ability to provide benefits to the community. Active participation from the town government, utility, and community groups is crucial to designing a microgrid that meets the community's needs. Additional detail about costs and benefits by stakeholder group can be found in Section 3.2.3.

2.3 Distributed Energy Resources Characterization (Sub Task 2.3)

As described above, the Watervliet microgrid design includes 450 kW of spinning generation and 160 kW of solar energy capacity. This section will discuss the benefits of the proposed resources and how they will meet the microgrid's objectives in greater details.

2.3.1 Existing Generation Assets

The Watervliet microgrid will incorporate the existing solar arrays at the Senior Citizen Center/Public Library and the Fire Station (see Table 4 for details on existing generation assets). The solar arrays will operate on an intermittent basis throughout the year. In addition to these solar arrays, there are two existing natural gas backup generators at the Fire Station and Police Department. Both of these backup generators have a nameplate capacity of approximately 30 kW. The Project Team considered including the natural gas generators in the microgrid's DER portfolio, but determined that the costs of switchgear, controllers, and necessary infrastructure would outweigh the benefits provided by their minimal generation capacity.

Most existing generators require switchgear and controllers to be integrated into the microgrid control scheme. However, because the existing solar arrays are relatively small, their output will have relatively little effect on power stability in island mode. It is therefore not necessary to include the arrays as controllable generation resources through the MCS. Existing inverters and internal breakers will allow the arrays to operate as part of the microgrid in grid-connected and islanded mode, but the MCS will not be able to regulate their output.

Table 4. Existing Distributed Energy Resources

Table describes the existing DERs to be incorporated into the microgrid, including their description, fuel source, capacity, and address. Table also provides each asset's label for Figure ES-1.

Name	Description	Fuel Source	Capacity (kW)	Address
DER2	Existing Solar Panel (Senior Citizen Center/Public Library)	Sun Light	30	1501 Broadway Ave
DER3	Existing Solar Panel (Fire Station)	Sun Light	30	116 13th St

2.3.2 Proposed Generation Assets

The microgrid design includes two new generation assets: a 450 kW natural gas-fired continuous duty reciprocating generator and a 100 kW solar PV array, as shown in Table 5. The reciprocating generator will be constructed at the Senior Citizen Center/Public Library and the solar array will be located on the rooftop of the Hudson Shores Plaza building. Existing natural gas infrastructure in Watervliet can support continuous operation of the reciprocating generator.

Table 5. Proposed Generation Assets

Table shows the rating, fuel, and address for the proposed generation asset. Table also provides its label for Figure ES-1.

Name	Technology	Rating (kW)	Fuel	Address
DER1	New Natural Gas Reciprocating Generator (Senior Citizen Center/Public Library)	450	Natural Gas	1501 Broadway Ave
DER4	New Solar PV Array (Hudson Shores Plaza)	100	Sun Light	1545 Broadway Ave

2.3.3 Generation Asset Adequacy, Resiliency, and Characteristics

The proposed design provides Watervliet with two new energy resources and ties two existing resources to critical facilities, allowing them to support critical services during emergency outages. In grid-connected mode, the 450 kW reciprocating generator and solar arrays will operate in parallel with the main grid, exporting excess power when generation exceeds demand and importing power from the larger grid to meet peak demand when necessary. In islanded mode, the microgrid control system (MCS) will first deploy energy from the solar arrays, and then manage output from the reciprocating generator to meet remaining demand. The reciprocating generator is sized to meet the entire microgrid load under typical conditions including daily peaks. If the microgrid's peak load does exceed the 2014 peak demand load curtailment will likely be required. Should load curtailment be required, the microgrid control system will disconnect the Hudson Shores Plaza facility in order to maintain power to the rest of the microgrid.

Although the team is still determining details on how to protect the generators from weather, the design will ensure they are safe from rain, snow, strong winds, or falling trees. At minimum, the new natural gas reciprocating generator will be placed in an enclosure on the Senior Citizen Center/Public Library's land. The natural gas pipeline is buried to protect it from severe weather.

The proposed natural gas reciprocating generator will be capable of supplying reliable electricity by providing:

- Automatic load following capability – the reciprocating generator will be able to respond to frequency fluctuations within cycles, allowing the microgrid to balance demand and supply in island mode.
- Black start capability – the reciprocating generator will have auxiliary power (batteries) for black starts and can establish island mode grid frequency. After the generator has established stable power flow, the main microgrid controller will synchronize the 100 kW solar array to match the reciprocating generator's frequency and phase.
- Conformance with New York State Interconnection Standards.[13]

[13] New York State Public Service Commission. *Standardized Interconnection Requirements and Application Process for New Distributed Generators 2 MW or Less Connected in Parallel with Utility Distribution Systems* (2014). Available from *www.dps.ny.gov*.

2.4 Load Characterization (Sub Task 2.2)

The Project Team sized proposed DERs according to electricity demand data from Watervliet's load points. The load characterizations below describe the electrical loads served by the microgrid.[14] Descriptions of the loads to be served by the microgrid along with redundancy opportunities to account for downtime are included below. None of the connected facilities have sufficient thermal energy demand to merit addition of combined heat and power capability to the proposed reciprocating generator.

2.4.1 Electrical Load

The Project Team evaluated eight primary electrical loads and two groups of residential facilities for the Watervliet microgrid (see Table 6 for a list of microgrid facilities). Typical 24 hour load profiles for each facility (or group of facilities) can be found in the Appendix. Watervliet's proposed community microgrid will incorporate a fire station, police station, the local senior citizen center, and low income housing units, all within close proximity to the primary National Grid feeder on Broadway Ave (Maplewood Station 307).

Table 6. City of Watervliet List of Prospective Microgrid Facilities

List of potential microgrid facilities, including their addresses, reference key for Figure ES-1, and classifications.

Map	Property	Address	Classification
F1	**Police Station/City Hall**	2 15th St	Public
F2	**Fire Station**	116 13th St	Public
F3	**Memorial Recreation Center**	Corner of 13th Street & 2nd Avenue	Public
F4	**Senior Citizen Center/Public Library**	1501 Broadway	Public
F5	**Civic Center**	14th St.	Public
F6	**Public Work Department**	1200 2nd Avenue	Public
F7	**Hudson Shores Plaza**	1545 Broadway	Residential
F8	**United Methodist Church**	1401 1st Ave	Community
F9	**Residential Group #1**	1409-1433 1st Ave	Residential
F10	**Residential Group #2**	1307-1335 1st Ave	Residential

The microgrid design requires a new medium-voltage electric distribution line (hereafter referred to as an "express line" because it does not energize intervening loads) to connect the Fire Station and Public Work Department to the remainder of the microgrid footprint. The line will run from the Memorial Recreation Center to the Fire Station and Public Work Department building. Currently, the Public Work Department is electrically served by a separate 4.16 kilovolt (kV) feeder. The other loads in the microgrid footprint are all on the 13.2 kV line on Broadway Avenue necessitating the replacement of the overhead transformer at Public Work Department building and express line to join with the 13.2 kV line. The microgrid will also require upgrades to three existing manual switches along National Grid feeders, installation of a new switch at the Hudson Shores Plaza building, and new equipment to connect the reciprocating generator and proposed solar array to the microgrid's electrical and communication systems. An existing fuse,

[14] Estimated loads are based on metering data from the facility's account numbers via National Grid's on-line database. However, the Project Team was unable to obtain load data for Hudson Shores Plaza. Average and peak load data for Hudson Shores Plaza were estimated based on real data from a similar facility in New Rochelle, New York.

downstream from the proposed reciprocating generator and the Senior Citizen Center/Public Library, will stop current from flowing to the rest of the microgrid if it becomes overloaded. Figure 1 provides an illustration of the proposed microgrid design and layout, including loads, switches, existing electrical infrastructure, and proposed electrical infrastructure. For a more detailed representation of the proposed electrical infrastructure, refer to Figure 3 (one-line diagram).

Figure 1. Watervliet Equipment Layout

Figure shows the microgrid equipment layout, illustrating DERs, distribution lines, load points, servers and workstations, network switches, and proposed distribution switches.

National Grid provided the Project Team with twelve months of metering data for connected facilities (January through December 2014), summarized in Table 7. The aggregate peak load in 2014 was 673 kW, and the monthly average was 314 kW.

Table 7. Watervliet's 2014 Microgrid Load Points

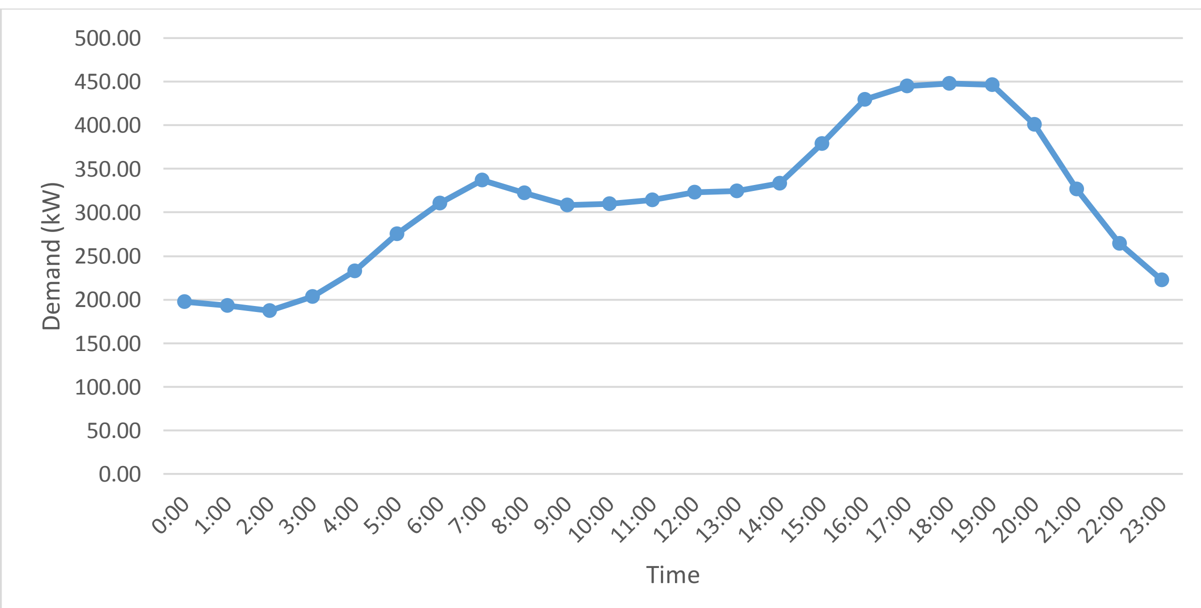
Table shows the microgrid electric demand in kW, electric consumption in kWh, and thermal consumption in MMBTU.

	Electric Demand (kW)		Electric Consumption (kWh)			Thermal Consumption (MMBTU)[15]		
	2014 Peak	2014 Average	2014 Annual	2014 Monthly Average	2014 Weekly Average	2014 Annual	2014 Monthly Average	2014 Weekly Average
Microgrid Loads	673	314	2,756,726	229,727	53,425	13,548	1,129	263

Figure 2 provides a typical aggregate hourly load profile for the Watervliet microgrid. Aggregate demand gradually increases around dawn and peaks from around 16:00 to 19:00, at which point demand returns to the night-time baseline. The cumulative demand curve is largely driven by the Hudson Shores Plaza facility, which represents around 69% of the microgrid's aggregate load.[16]

Figure 2. Typical 24-Hour Cumulative Load Profile

Figure 2 illustrates the typical 24-hour cumulative load profile for connected facilities. The figure represents the sum of individual typical 24-hour load profiles.



[15] Despite the thermal load indicated in this table, thermal consumption in Watervliet is predominantly heating. It is performed by a system or systems which cannot be replaced by a CHP unit. None of the thermal off-takers can support a CHP facility in Watervliet.

[16] The Project Team was unable to obtain interval load data for the Hudson Shores Plaza facility, so the typical load profile included in the Appendix is simulated based on a typical load profile for a mid-rise apartment building.

The 450 kW reciprocating generator and solar arrays will operate continuously in both grid-connected and islanded mode. Although the solar arrays will not operate at name plate capacity throughout the year, they will typically be most productive when facility demand is highest.

When the solar arrays are operating close to their maximum production points, the microgrid's generation capacity will approach 610 kW, with a guaranteed 450 kW from the reciprocating generator. Aggregate demand from microgrid facilities averaged 314 kW and never exceeded 673 kW in 2014.[17] The proposed DERs will typically have adequate capacity to supply all of the microgrid facilities with electricity in island mode. However, if aggregate demand exceeds available generator capacity, the microgrid control system will open the proposed switch at the Hudson Shores Plaza building (SW 6 in Figure 3) in order to shed this load and maintain power to critical facilities within the coverage area.

The Project Team expects some degree of natural load growth after construction of the microgrid. Because the reciprocating generator is sized to approximately match current facility demand, significant load growth could threaten the reliability of the microgrid's electricity supply in island mode. Microgrid facilities can mitigate this threat by investing in EE upgrades or intelligent building energy management systems that respond to commands from the main microgrid controller. Microgrid owners may also invest in additional supply-side resources such as small dual-fuel generators or battery storage systems.

Because the microgrid design relies heavily on the reciprocating generator as the primary energy source, connected facilities will be forced to rely on grid-supplied power if the reciprocating generator goes offline for maintenance.

2.4.2 Thermal Consumption

The Project Team conducted an extensive study on connected facilities to determine whether the design could include a combined heat and power unit. None of the connected facilities have sufficient thermal energy demand to merit addition of CHP capability.

2.5 Proposed Microgrid Infrastructure and Operations (Sub Task 2.1)

The existing distribution system infrastructure will be expanded and modified to accommodate microgrid operations. The microgrid will support two fundamental modes of operation: grid-connected (normal or grid paralleling) and islanded (emergency) modes. Details concerning the infrastructure and operations of the proposed microgrid in normal and emergency situations are described below.

2.5.1 Grid Parallel Mode

The microgrid will most often operate in grid-connected mode. In this mode, the microgrid's generation assets will operate continuously, supplying energy to microgrid-connected facilities and potentially exporting excess energy to the larger National Grid system. Standard off-the-

[17] This estimate was calculated by summing each facility's peak demand from 2014. The estimate therefore assumes that all facilities reached peak demand at the same time, which is unlikely. The true peak demand was almost certainly less than 673 kW, but the Project Team was unable to obtain synchronized real-time load data for all included facilities.

shelf components will allow the microgrid to import power from the larger National Grid grid and back-feed excess power when generation exceeds microgrid demand. Refer to Table ES-2 for a complete list of microgrid DERs.

If the larger grid experiences a power emergency while the microgrid is connected, the microgrid control scheme allows for the export of a predetermined amount of active and reactive power from microgrid DERs. By injecting power into the larger grid, the microgrid may be able to balance frequency and voltage to avert an outage. If the 450 kW reciprocating generator has sufficient capacity, it will ramp up generation as necessary to fulfill the necessary power requirement.

2.5.2 Intentional Islanded Mode

The proposed energy management and control scheme will balance generation with microgrid demand and maintain adequate frequency, voltage, and power flow across the microgrid network in islanded (autonomous) mode (as described in Section 2.7.4). The microgrid will intentionally switch to islanded mode during forecasted National Grid outages or disturbances to maintain electricity supply for microgrid facilities. In islanded mode, the system will first deploy available energy from the solar arrays and then manage the reciprocating generator to match remaining demand in real time. Because the output of the solar arrays cannot be controlled, the natural gas generators will provide flexible real-time response.

The microgrid will not intentionally switch to island mode for economic reasons (i.e., to participate in demand response programs or beat prices on the spot market) because doing so would disconnect downstream facilities from the Maplewood Station 307 feeder resulting in a loss of power to those facilities. Refer to the simplified one-line diagram in Figure 3 for a detailed device representation showing both existing and proposed generation assets, utility interconnection points, and switches that will isolate the microgrid from the local National Grid feeder.

2.6 Electrical and Thermal Infrastructure Characterization (Sub Task 2.4)

This section describes the electrical and thermal infrastructure of the proposed microgrid. The infrastructure resiliency, the point of coupling (PCC), and the proposed utility infrastructure investment are also fully discussed below.

2.6.1 Electrical Infrastructure

The local utility, National Grid, owns the existing electrical infrastructure in the City of Watervliet. Maplewood Station 307 is the primary feeder in the area, but there may be additional feeders that can supply the City with power. If this is the case, National Grid has the option of using another feeder as a redundant secondary supply of electricity. However, this study assumes that the City can only receive power from the Maplewood Station 307 feeder.

The PCC with the National Grid system will be located along the Maplewood Station 307 feeder (SW1 in Figure 3). The existing manual switch at the PCC will need to be upgraded to serve its function in the microgrid control scheme. Two other existing manual switches on 1st Avenue

(SW4 in Figure 3) and 15th Street (SW3 in Figure 3) will also need to be upgraded to respond to commands from the microgrid control system. These switches will disconnect downstream non-microgrid loads from the Maplewood Station 307 feeder. Finally, the design requires installation of a new automatic switch (SW6 in Figure 3) at the Hudson Shores Plaza building to allow real time load shedding in island mode.

The reciprocating generator and 100 kW solar PV array will require switchgear and controllers to communicate with the microgrid control system; however, the existing 30 kW solar arrays will not require new switchgear and controllers because their output will have relatively little impact on power stability. See Figure 1 for a map of proposed equipment and infrastructure. For a detailed outline of microgrid equipment, see the one-line diagram in Figure 3.

The following tables (Table 8 to Table 10) describe the microgrid components and are referenced throughout the rest of the document. To see a list of all included DERs, see Table ES-2.

Table 8. Watervliet Distributed Switches Description

Table outlines all six distributed switches with their names (for reference to the equipment layout), descriptions, and status as proposed.

Name	Description	New/Upgrade
SW1	Automatic switch for feeder isolation	Upgrade
SW2	Generator Breaker (for reciprocating generator)	New
SW3	Automatic switch for non Microgrid load isolation	Upgrade
SW4	Automatic switch for non Microgrid load isolation	Upgrade
SW5	Generator Breaker (for PV array)	New
SW6	Automatic switch for load shedding	New

Table 9. Watervliet's Network Switch Description

Table outlines all five network switches with their descriptions, status as existing or proposed, and addresses.

Name	Description	Status	Address
NS1	Near Switches 1, 5, and 6 for communication	Proposed	Refer to Eqp. Layout
NS2	Near DER 1 for communication	Proposed	Refer to Eqp. Layout
NS3	Near Switch 3 for communication	Proposed	Refer to Eqp. Layout
NS4	Near Switch 4 for communication	Proposed	Refer to Eqp. Layout
NS5	Near microgrid main controller (Supervisory Control and Data Acquisition (SCADA)/EMS) and Workstations for communication	Proposed	2 15th St

Table 10. Watervliet's Server Description

Table describes the workstation and servers, their status as proposed, and their addresses.

Name	Description	Status	Address
Workstation	Operator/Engineer workstation	Proposed	2 15th St
Server1	Primary EMS and SCADA	Proposed	2 15th St
Server2	Secondary EMS and SCADA	Proposed	2 15th St

The National Grid distribution system in Watervliet consists of medium voltage lines (13.2 kV). All branches off these medium voltage lines have their own transformers that step incoming power down to low voltage.

Figure 3. Watervliet One-Line Diagram

Figure displays a one-line diagram for Watervliet illustrating interconnections and lay-out.

REDACTED PER NDA WITH NATIONAL GRID

2.6.2 Points of Interconnection and Additional Investments in Utility Infrastructure

The proposed components and interconnection points for the Watervliet community microgrid are listed in Table 11. The PCC between the main grid and the microgrid will be located along the Maplewood Station 307 feeder—the existing manual switch at the PCC will need to be upgraded to respond to commands from the MCS. Similar upgrades are necessary for the existing manual switches on 15th Street and 1st Avenue, which will disconnect downstream loads from the primary National Grid feeder. The new reciprocating generator and 100 kW solar PV array will require controllers and switchgear to regulate and, if necessary, disconnect their output. However, the existing 30 kW solar arrays do not require generation controllers or switchgear because their output will have relatively little impact on the microgrid's power stability in island mode.

The current microgrid design allows the MCS to disconnect the Hudson Shores Plaza facility in islanded mode when aggregate demand exceeds available generation capacity, but does not allow the shedding of other loads. The MCS will maintain system stability by regulating the reciprocating generator's output in response to fluctuations in system frequency and voltage.

Table 11. List of Additional Components

Table lists all proposed microgrid devices/components.

Device	Quantity	Purpose/Functionality
Microgrid Control System Protocol Converter (Siemens SICAM PAS or equivalent)	1 Primary 1 Back-up	Protocol Converter responsible for operating the microgrid's field devices via protocol IEC-61850.
Automated Pole Mount Circuit Breaker/Switch (Siemens 7SC80 relay or equivalent)	3	Upgraded breakers/switches at 2 overhead distribution switches. These switches isolate downstream loads from the microgrid. One new switch at Hudson Shores Plaza will allow load shedding in island mode.
Automated Underground Circuit Breaker/Switch (Siemens 7SJ85 relay or equivalent)	1	Upgraded breaker at SW1. Disconnects the microgrid from primary feeder.
Generation Controls (OEM CAT, Cummins, etc.)	1	Serves as the primary resource for coordinating the paralleling load matching and load sharing of the reciprocating generator.
PV Inverter Controller (OEM Fronius or equivalent)	1	Controls PV output and sends data to MCS for forecasting.

Network Switch (RuggedCom or equivalent)	5	Located at IEDs and controllers for network connection, allowing remote monitoring and control.

All microgrid devices will require a reliable source of direct current (DC) power. Each device (or cluster of devices) will have a primary and backup power supply source. During normal operation, 120 volt alternating current (VAC) power will flow through an alternating current (AC) /DC converter to power the microgrid devices and maintain the charge of the DC battery banks. The device current draw (amperage used by each device) should not exceed 60% of available power supply. When the normal AC voltage source is unavailable, the battery bank can provide DC power to devices for at least one week.

2.6.3 Basic Protection Mechanism within the Microgrid Boundary

The power system protection system senses grid variables, including voltage, current, and frequency, and takes necessary actions (such as de-energizing a circuit line) to maintain these variables at appropriate levels. Protection schemes are currently based on the assumption that power flows in one direction. Microgrid operations, particularly during island mode, require bidirectional power flow. This will introduce difficulties for protection coordination. At a later design stage, the microgrid designer will have to perform protection studies accounting for the key characteristics of island mode, which include possible bidirectional power flows and very low fault current detection.

The current design includes controls that can prevent back-feeding of power to the larger National Grid system or allow the export of excess energy back to National Grid.

2.6.4 Thermal Infrastructure

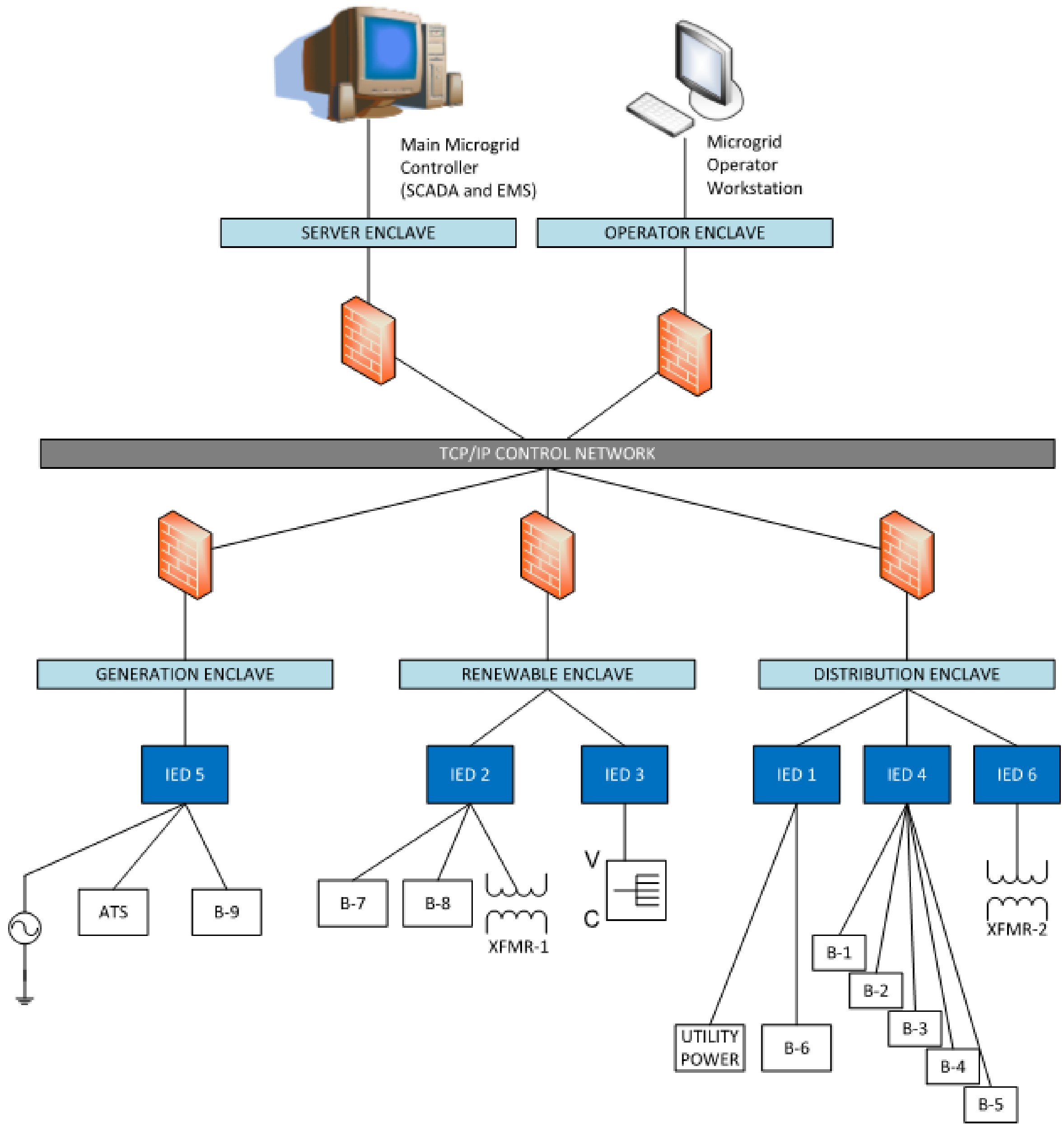
The proposed natural gas reciprocating generator requires a steady supply of natural gas to operate. The reciprocating generator will utilize existing thermal infrastructure in Watervliet for its fuel supply—a 6 inch low pressure line runs along the building's west side. If the reciprocating generator requires higher pressure gas, it may tap into a 12 inch medium pressure (24 psi) pipe that runs along 2nd Avenue. Neither of these pipelines will require significant upgrades or extensions to bring gas to the proposed generator. The current proposed generator only requires 3-5 psi of pressure at its intake, therefore, the existing thermal infrastructure is conducive for the stated generator.

2.7 Microgrid and Building Control Characterization (Sub Task 2.5)

This section provides a more detailed description of the microgrid's modes of operation. The microgrid control system will include an EMS and a SCADA based control center (see Figure 4), hereafter collectively referred to as the main microgrid controller or MCS. Distributed intelligent electronic devices (IEDs) will communicate with the main microgrid controller over the local Transmission Control Protocol/Internet Protocol (TCP/IP) network. In grid-parallel mode, the microgrid will synchronize frequency and voltage magnitude with the larger grid and will have the potential to export excess electricity to National Grid. When controllers detect an outage or emergency disturbance on the larger grid, the microgrid will switch to island mode. In these situations, the microgrid will disconnect from the larger grid and proceed with the programmed black start sequence (described in Section 2.7.6) to start power flow through included lines and devices. When power returns after an outage, the main microgrid controller will manage re-synchronization to the National Grid system (described in Section 2.7.7).

Figure 4. Diagram of a Typical Microgrid Control System Hierarchy

The following network diagram illustrates a microgrid control network with a generator, breakers, transformers, an automatic transfer switch (ATS), IEDs (which could be actuators, Meters, Accumulators, or Programmable Logic Controllers (PLCs)), an Energy Management System, a renewable energy source, and a SCADA client and server.



2.7.1 Microgrid Supporting Computer Hardware, Software, and Control Components

The following is a preliminary list of the hardware components needed for the City of Watervliet's microgrid:

- Energy sources – The microgrid requires DERs in order to supply electricity to connected facilities. To some degree, flexible loads that can be reduced during peak demand events may also be considered as energy sources.
- Microgrid Control System – The MCS is composed of an Energy Management System and Supervisor Control and Data Acquisition (SCADA) based control center. The MCS is responsible for logging relevant data, regulating generator output, curtailing flexible loads (where possible), and managing transitions between modes of operation.
- Distributed breakers, switches and controls – The microgrid requires automated switches and breakers to disconnect downstream loads and regulate generator output. The MCS is capable of maintaining power stability by shedding non-critical loads, but only the Hudson Shores Plaza facility will be equipped with the necessary equipment to do so.
- Utility breakers and controls – These automatic controls will interface between the microgrid and the local National Grid feeder (Maplewood Station 307).
- New electric distribution line – A new medium-voltage express line will be necessary to connect the Fire Station and Public Works Department to the other facilities. This line will run from the Recreation Center to the Fire Station.
- Generator controls/relays – These components will be installed at each generating unit/inverter. They will control generator output based on signals from the MCS.

The proposed system uses a Service Oriented Architecture (SOA) software platform that will serve as the messaging and integration platform for the monitoring and control of distributed equipment. The SOA system supports almost any power device or control system from any major vendor and therefore ensures communication networkability and interoperability between competing vendor systems. The computer hardware and software required for a fully automated operational microgrid design are as follows:

- SOA software platform – The SOA platform facilitates the monitoring and control of included power devices and control systems.
- Two RAID 5 servers (Redundant Array of Independent Disks) (including 1 primary, 1 backup) for the MCS – The MCS will include an EMS and a SCADA based control center, and will optimize the operation of the microgrid. This includes determining which critical loads will be supplied, integrating PV output into the energy portfolio (including high resolution solar forecasting), and controlling the charge/discharge of energy storage wherever applicable. The system combines information on power quality, utilization, and capacity in real time, which allows the community and control algorithms to balance electricity supply with microgrid demand.
- Historian database server – Historian database collects and logs data from various devices on the network.

- Applications server (one or more) – Depending on the software and hardware vendors' preference, application servers may be used for numerous purposes. Common uses for an application server include backup and recovery, antivirus, security updates, databases, a web server, or use as some other software depending on how the SCADA and EMS vendors configure their platform.
- Operator workstations for SCADA and EMS – Workstation computers, sometimes called thin-clients, allow operators to view real-time data and control the microgrid from the SCADA control room or a remote location. Users must have proper access rights and permissions to operate workstation computers.
- Automated pole mount circuit breaker/switch (Siemens 7SC80 relay or equivalent) – The microprocessor based logic controllers in the field, also referred to as intelligent electronic devices, are programmed to act on predetermined set points. They can also be manually overridden by the MCS or a human operator. The control system host servers continuously poll these logic controllers for data using discrete or analog signals. Resulting data is processed by the IEDs connected to control elements. Three existing manual switches will be upgraded with these components and will disconnect downstream loads from the microgrid. One new automated switch will disconnect the Hudson Shores Plaza facility as necessary in response to signals from the MCS.
- Automated underground circuit breaker/switch (Siemens 7SJ85 relay or equivalent) – Similar to the pole mount circuit breakers, this IED can act on predetermined set points or can be controlled by an operator via the microgrid control center. This component represents an upgrade to the manual switch at the proposed point of common coupling with the Maplewood Station 307 feeder.

Use of the listed hardware, software, and resources must be synchronized to maintain stable and reliable operation.

2.7.2 Grid Parallel Mode Control

When the microgrid operates in grid-connected mode, each generator under MCS control will synchronize its voltage (magnitude and angle) and frequency with the voltage (magnitude and phase) and frequency of the electrically closest interconnection point with the main grid. After initial synchronization, the generator voltage phase will drift away from the main grid's voltage phase, which will allow the flow of active and reactive power. The generator's voltage magnitude and frequency will be maintained as close as possible to the main grid's voltage magnitude and frequency. Generation assets will follow the Institute of Electrical and Electronics Engineers (IEEE) 1547 standard for interconnecting distributed resources with electric power systems. The IEEE 1547 and other DER interconnection standards required by utilities are applicable to synchronous, asynchronous, and inverter-based generation.

National Grid might have additional technical and economic requirements if the microgrid plans to export energy or provide ancillary services to the distribution grid. The proposed reciprocating generator is capable of providing ancillary services to the National Grid system. It can provide reactive power and frequency response services on demand, but providing reactive power support may diminish the generator's ability to generate real power.

Please refer to the **Error! Reference source not found.** in the Appendix for the control scheme sequence of operations.

2.7.3 Energy Management in Grid Parallel Mode

The proposed microgrid will integrate software and hardware systems to ensure reliability and effective performance. Optimization of microgrid performance involves three distinct phases: measurement and decision, scheduling and optimization, and finally execution and real time optimization.

Data logging features will allow the main microgrid controller to measure historical performance and track significant trends. Human operators can use this data to prioritize loads, manage generator output, and schedule maintenance for generators and microgrid components. The microgrid executive dashboard will collect and filter information on the current operating strategy as well as performance metrics for SAIFI (System Average Interruption Frequency Index), SAIDI (System Average Interruption Duration Index), and CAIDI (Customer Average Interruption Duration Index), all adjusted to reflect the high sampling frequency of the system. Other performance metrics include power interruptions (defined as 50% variance of predicted voltage to measured voltage for 10 minutes or longer), voltage violations (defined as variance of actual voltage to predicted voltage for 5 minutes), and frequency violations (defined as variation to predicted frequency of more than 0.2 Hz for more than 10 minutes). The executive dashboard will calculate daily, weekly, and monthly rolling totals for all of these metrics.

After analyzing historical trends and monitoring real-time data, the main microgrid controller will optimize operation of the microgrid by managing generator output and flexible loads wherever possible. In grid-connected mode the microgrid controller will prioritize the deployment of renewable generation and will aim to offset electrical demand whenever possible.

2.7.4 Islanded Mode Control

The transition to island mode can be either unintentional or intentional. Unintentional islanding is essentially the main microgrid controller's programmed response to an outage at the distribution system or transmission level. An outage at the distribution system level can occur within or outside the microgrid, and the microgrid islanding scheme must be able to handle either situation. MCS relays at the PCC will recognize low voltage, and the upgraded switch at the PCC will open automatically (disconnecting the microgrid from the Maplewood Station 307 feeder). If the reciprocating generator and 100 kW solar array are on-line, they will be isolated and ramped down via generation breakers. The 30 kW solar PV arrays are too small to have a significant effect on this process and will remain on-line throughout the transition. All microgrid loads and distribution switches will then be switched open via designated circuit breakers and relays to prepare for local generation startup. Using the reciprocating generator's black-start capabilities, the MCS will commence island mode operation. The reciprocating generator will ramp up to 60 Hz and prepare to supply each of the microgrid loads in sequence. After the reciprocating generator is on-line and power flow through the microgrid is stable, the MCS will synchronize output from the 100 kW solar array (voltage and frequency) and bring it on-line. In steady state, its phase will be different, similar to grid-connected steady state operation.

The microgrid will intentionally switch to island mode if:

- The National Grid system has an expected outage which could potentially affect transmission power to Watervliet substations.
- National Grid needs to perform network maintenance work, thereby isolating loads in the Watervliet area.

The intentional transition to island mode begins when the system operator sends the command to prepare for islanding. The main microgrid controller will automatically start and parallel the reciprocating generator and 100 kW solar array. Once output from the available power sources is synchronized, the system is considered ready to implement islanded operation and will begin opening the incoming utility line breakers. Under intentional islanding, the transition to island mode is seamless and closed (it does not require black start).

Please refer to **Error! Reference source not found.** for the control scheme sequence of operation in the Appendix.

2.7.5 Energy Management in Islanded Mode

After completing the transition to island mode, the MCS will perform a series of operational tests to ensure that the microgrid is operating as expected and that power flow is stable and reliable. The MCS will gather data on power flow, short circuit, voltage stability, and power system optimization using an N+1 (N components plus at least one independent backup component) contingency strategy to determine if additional load can be added. The N+1 strategy ensures extra generation is always on-line to handle the loss of the largest spinning generator and assumes the running generator with the highest capacity could go off line unexpectedly at any time. If aggregate demand exceeds available generation capacity in island mode, the MCS will disconnect the Hudson Shores Plaza facility in order to maintain power to the rest of the microgrid.

The microgrid must also be capable of handling any contingencies that may occur within the islanded system. These contingencies include:

- Generators that do not start. The reciprocating generator is currently the microgrid's only connected spinning generator, but the microgrid may expand in the future to include backup generators or new generators.
- Generators that trip off unexpectedly during microgrid operation.
- Switchgear that fails to operate.
- Switchgear that fails to report status.
- Loss of power from the natural gas generator.
- Loss of power from the solar arrays.

When the microgrid operates in island mode, the reciprocating generator and 100 kW solar array must produce power at the same voltage magnitude and frequency. However, the voltages of electrically distant generators will be of different phase. The MCS will continuously balance generation and load in real-time, monitoring relevant variables (i.e., system frequency and voltage) and adjusting generator output as necessary. It will first deploy energy from renewable generation assets and adjust output from the reciprocating generator to match remaining electricity demand. The microgrid design relies on the reciprocating generator's fast ramp rate to compensate for changing output from the solar arrays.

While battery storage is an alternative method by which the intermittency of solar output can be mitigated, the Booz Allen Team found the cost of battery storage to be prohibitively high for Watervliet's microgrid system. The analysis considered the potential of using storage for three purposes:

- System reliability: Short term back-up, often used for voltage or frequency support or to smooth intermittent renewable ramp rates.
- Energy shifting: Storing excess generation for a few hours, usually to offset higher priced periods (e.g., shifting excess solar generation from 1-3 PM to 4-6 PM when grids tend to peak).
- Longer term storage: Storing energy from intermittent renewables for later use to firm up the supply to 24 hours or to improve/extend island mode operation.

The analysis indicated storage was not needed to improve system reliability (the fast ramp rates of included spinning generator provides an acceptable level of reliability). The high cost of battery storage and absence of time-of-use energy rates challenged the economics of using storage to shift generation or extend island mode operation.

2.7.6 Black Start

The proposed 450 kW reciprocating generator will be equipped with black start capabilities. If the Watervliet grid unexpectedly loses power, the main microgrid controller will initiate island mode by orchestrating the predefined black start sequence. The microgrid then begins an un-intentional transition to island mode. A DC auxiliary support system is an essential part of each generator's black start capabilities. Each battery backup system must have enough power to start the generator multiple times.

When the larger grid unexpectedly loses power, the main microgrid controller orchestrates the black start sequence as follows:

1. PCC breaker opens
2. All active generation is disconnected (with the exception of the 30 kW solar PV arrays, which will not have a significant impact on synchronization or power stability)
3. The main microgrid controller waits a pre-set amount of time (approximately 30 seconds) in case power is restored to the larger grid

4. The main microgrid controller disconnects the entire current load (after estimating aggregate electricity demand)
5. The reciprocating generator and 100 kW solar array are synchronized with each other (one will usually provide reference voltage and frequency)
6. The main microgrid controller reconnects the microgrid loads based on the available generation

The MCS will manage any contingencies that arise during the black start operation (e.g., if breakers do not respond to trip commands and the microgrid does not properly disconnect from the larger grid). If the reciprocating generator does not start as expected during a utility outage, the microgrid control system is equipped with contingency algorithms to appropriately manage the situation. If possible, the control system will still isolate the microgrid.

If more generators are added in the future, the MCS will allow operators to designate certain generators as unavailable for participation in the microgrid (e.g., if they require maintenance) so that the generator dispatch algorithms can accommodate a reduced available capacity.

Please refer to the **Error! Reference source not found.**in the Appendix for the control scheme sequence of operations.

2.7.7 Resynchronization to National Grid Power

When power is restored to the larger grid, the main microgrid controller will coordinate a safe and orderly re-connection. The system will first wait a predefined, configurable time period to ensure that power has been reliably restored and then will commence resynchronization with the National Grid power supply. As a final check, the system operator will either receive an automated notification or directly contact National Grid to confirm that power flow on the larger grid is on-line and stable.

While operating in island mode, the system will constantly monitor the status of the larger grid at the PCC and determine when appropriate levels of current and voltage have been restored. When power is restored, the MCS will disconnect the 100 kW solar array and synchronize output from the reciprocating generator with the utility service through the utility circuit breaker. Before the microgrid system starts paralleling with the utility, it will balance local generation and load so as not to exceed both minimum or maximum export limits and time durations set forth in the utility interconnection agreement. When microgrid power flow has been synchronized to the larger grid, the main microgrid controller will bring the 100 kW solar array back on-line.

Please refer to Watervliet Microgrid Operation One-Line: Parallel Mode (from Islanded Mode) in the Appendix for control scheme sequence of operations.

2.8 Information Technology and Telecommunications Infrastructure (Sub Task 2.6)

The existing information technology (IT) and telecommunication infrastructure in Watervliet is best suited for a wireless microgrid communication system. The network will rely on several existing network switches distributed throughout the City. The communication system and network switches (which have local backup batteries) will communicate wirelessly with the base station located at the Police Station/City Hall building, which is electrically served by the microgrid in islanded mode. During the intermittent stage, or black-start sequence mode, the headend IT network equipment and base station for the IT network communications system will be powered by their backup batteries. The microgrid design requires minimal additional hardware (i.e., the network switches, WiMax Base Station, WiMax subscriber units, servers, and computers required to manage a microgrid) to seamlessly integrate with the IT system.

2.8.1 Existing IT & Telecommunications Infrastructure

Watervliet already takes advantage of its existing fiber optic backbone ring and existing Ethernet switches for reliable Internet and Local Area Network (LAN) activities, making convergence quite feasible. The wireless components of the control system, which work on open architecture protocols, use a TCP/IP Ethernet-enabled component that controls each of the uniquely addressed modules to wirelessly communicate via a standard, non-licensed radio frequency mesh 900 megahertz (MHz) industrial scientific and medical (ISM) band signal network.

2.8.2 IT Infrastructure and Microgrid Integration

New hardware and software will be required to ensure compatibility between the existing IT infrastructure and proposed microgrid system. There are seven main components required for any microgrid system to successfully integrate with an IT/telecommunication infrastructure: host servers, application servers, operator workstations, network switches, network-attached logic controllers, data transmission systems (either fiber or Ethernet cables), and the vendor agnostic SOA software that facilitates the monitoring and control of virtually any power device or control system. All of these critical parts work together and serve a specific role.

2.8.3 Network Resiliency

Cyber security falls into the two primary stages (1) design and planning, and (2) continuous operations. Cyber security is especially important for the microgrid control system as it utilizes TCP/IP protocols for compatibility amongst the distribution system. This convergence has also introduced vulnerabilities to the MCS because the MCS vendors have historically lagged behind in implementing security patches rolled out by Windows, or PC-based security teams.

For the planning stage, design considerations address cyber security by assigning roles to network-attached components on National Grid's WAN thereby controlling data flow and access permissions over the integrated MCS and overarching IT architecture.[18] For example, the design utilizes a network segmentation scheme by function (separate segments/enclaves for servers,

[18] Assumes the microgrid will utilize enterprise-level remote monitoring and control.

operators, generation, and distribution), in addition to network firewalls, for clean and continuous monitoring and control of data flow. The firewall routes noncritical traffic such as utility's unrelated corporate printers and other drivers, email, and all other non-essential internet services (which could be backdoors for hackers into the MCS) to a dedicated "demilitarized zone" usually consisting of a single security hardened server.

Because the logic controllers will be located at or near loads, the distributed equipment will take the IT system to the "edge" of National Grid's network, where it is potentially more vulnerable to hackers. Sticky media access control (MAC) is an inexpensive and practical program that can help prevent unauthorized access and protect the National Grid IT network. Every network attached device has a unique, unchanging MAC interface. The Sticky MAC program is configured to monitor the unique address of the device and its designated network port. If the device disconnects, the program disables the port and thus prevents an unauthorized device that may have malicious code from entering the IT system.

Physical security measures, such as electronic badge access or cipher combination hardware locksets, should also be considered. The Project Team recommends implementing physical security at the perimeter of the control center building and network communication closets where the switches reside.

The data transmitted throughout the proposed Watervliet microgrid will be encrypted, but several additional intrusion protection measures can easily be implemented. One simple and inexpensive method is to disable any of the 65,535 TCP ports not used to make the microgrid system work (depending on final configuration, only a few TCP ports will need to be active). More TCP ports will need to be active when the available enterprise-level monitoring and control access will be utilized.

Activating and analyzing security logs is also important. As a rule, the operating system and firewall can be configured so certain events (e.g., failed login attempts) are recorded. The security portion (software that resides on the control system servers) will be configured so only operators and engineers with specific login credentials can access and control the microgrid.

In the event of a loss of communication with the IT system, the microgrid will continue to operate. The programmed logic code for the network attached controllers is stored locally in each module, giving the controllers the ability to operate as standalone computers in the event of a disruption between the IT system and microgrid.

Cyber Security will also be considered during the operations stage to maintain against ongoing threats. Although MCS vendors in the past used to perform only minimal software regression tests for bugs; in recent years, the MCS vendors have been working on these issues continuously to mitigate security risks. It is important to note the proposed MCS network attached components can be upgraded on-line as software updates become available. The MCS could be upgraded automatically whenever an update is available or manually after testing the updates in a non-production environment. In either case, a networked server is used to deliver the updates. Each approach has its own benefits and drawbacks. Automatic upgrading installs updates as soon as they are available but they might not function as expected in the given environment. Upgrading manually allows for testing to ensure correct functioning but the upgrades might be delayed over automatic upgrades. In either case, a networked server is used to deliver the updates.

It is strongly recommended these updates be tested or simulated first in a non-production environment. The simulated model is easy to mimic with artificial (input/output) I/O points. Any reputable control systems programmer/integrator does such testing before the commissioning stage; the same I/O model and hardware configuration could be used for the security update tests in the future. The Team considers the safety and availability of the microgrid to be the most critical aspects of the microgrid. Testing and/or simulation of the system responses to software updates is important because it allows the owner or operator to identify any anomalies which the software updates might introduce to the overall system before full deployment in the field. Further considerations will be assessed during the next phase of the Prize initiative.

2.9 Microgrid Capability and Technical Design and Characterization Conclusions

After thorough examination of existing utility infrastructure and energy demand requirements, the Project Team has provided a reliable microgrid design. Control components will efficiently manage the real-time operation of the microgrid by communicating with distributed intelligent electronic devices. The proposed design is resilient to forces of nature and cyber threats, and offers full automation and scalability at every level. Its vendor agnostic SOA-based framework promotes interoperability between standard off-the-shelf components, ensuring continuous and smooth operation of the microgrid.

In conclusion, the project is technically feasible. The project requires a new medium-voltage express line to connect the Fire Station and Public Works Department to the other microgrid facilities and upgrades to three existing manual switches, which will disconnect the microgrid from the local feeder (Maplewood Station 307) and downstream non-connected loads. The design proposes a new 450 kW natural gas-fired reciprocating generator and a new 100 kW solar PV array, and ties two existing solar arrays into the microgrid's DER portfolio, ensuring that energy is available to critical facilities during emergency outages. Existing natural gas infrastructure in the City will support continuous operation of the proposed natural gas reciprocating generator throughout the year.

The main barriers to completion will be obtaining funding for the project's capital costs and constructing the new express line from the Recreation Center to the Fire Station and Public Works Department. The utility (National Grid) must also agree to the new interconnection and electrical distribution network because it will incorporate National Grid lines and switches. The Senior Citizen Center/Public Library and Hudson Shores Plaza need to agree to host the proposed reciprocating generator and solar array, and both the Senior Citizen Center/Public Library and Fire Station must allow interconnection of their 30 kW solar arrays. Existing and proposed generation assets and microgrid components must be available for maintenance at all times. The Team is still working with the facilities to ensure that they will allow a third party to service the generation assets and microgrid components located on their land. The Project Team expects these operational challenges to be resolved by the time of construction—these facilities have considerable incentive to support the project, as construction and interconnection will guarantee a reliable power supply and possibly provide distributed energy resource asset owners with new sources of revenue.

3. Assessment of Microgrid's Commercial and Financial Feasibility (Task 3)

The conclusions in this section are predicated on several fundamental assumptions:

- National Grid will own and operate the generation assets and the microgrid infrastructure. They have indicated an interest in doing so, and the Project Team believes this is the preferred path forward.
- Electricity is valued at the average supply charge paid by National Grid.

3.1 Commercial Viability – Customers (Sub Task 3.1)

The Watervliet microgrid will include the ten facilities identified in Table ES-1. National Grid will own and operated the proposed generation assets as well as the control microgrid infrastructure.

The Police Station/City Hall, the Fire Station, and the Senior Center/Public Library will all provide critical services (as defined by NYSERDA) to the City during emergency situations. These include shelter, general government functions, and life safety. Although the remaining facilities do not provide critical services, they can serve as shelters during emergencies and will allow more than 100 residents to remain in a powered home during any grid outage situation. There are two existing 30 kW natural gas generators, one at the Police Station and one at the Fire Station. However, the Project Team has chosen not to intertie these to the microgrid given the relatively high cost to do so for small generating assets. In the event of an outage, these generators could provide power to the facilities where they are located decreasing demand at those facilities, but power from the generators will not flow on to the microgrid system. The design requires minimal new lines, which will connect the Public Works Department and Fire Station to the correct feeder and voltage for microgrid participation. The project will affect several groups of stakeholders in Watervliet not physically connected to the microgrid; the benefits and challenges to these stakeholders are discussed further in this section.

3.1.1 Microgrid Customers

Two new generators will provide power to the Watervliet microgrid: a 450 kW natural gas-fired reciprocating engine and a 100 kW solar array. The microgrid will enter island mode when it detects an outage or disturbance on the National Grid system. The microgrid will also have the technical ability to enter island mode for maintenance or other reasons deemed important by

National Grid, but it is unlikely to do so regularly because downstream loads may be adversely affected. Moreover, the microgrid cannot island for economic reasons due to the downstream loads on the feeder system. This excludes the possibility of DR participation. Table 12 identifies each of the direct microgrid customers and the scenarios during which they will purchase electricity from the microgrid.

Table 12. Microgrid Customers

Facilities that will be connected to the microgrid.

Property	Address	Classification	Critical Service	Backup Generation	Normal vs Island Mode
Police Station/City Hall	2 15th St	Public	Yes	Yes	Both
Fire Station	116 13th St	Public	Yes	Yes	Both
Memorial Recreation Center	Corner of 13th Street & 2nd Avenue	Public	No	No	Both
Senior Citizen Center/Public Library	1501 Broadway	Public	Yes	No	Both
Civic Center (Red Cross Designated Shelter)	14th St.	Public	Yes	No	Both
Public Work Department	1200 2nd Avenue	Public	Yes	No	Both
Hudson Shores Plaza	1545 Broadway	Residential	No	No	Both
United Methodist Church	1401 1st Ave	Community	No	No	Both
Residential Group #1	1409-1433 1st Ave	Residential	No	No	Both
Residential Group #2	1307-1335 1st Ave	Residential	No	No	Both

Cash flows from electricity sales will consistently cover variable costs and yield positive operating revenues. There are no rebates available for the natural gas unit, though the Federal solar Investment Tax Credit (ITC) will recover around 30% of the capital cost of the solar array. The project requires a minor investment in new overhead lines, estimated at $30,000. With the aforementioned incentives and rebates, the overall system does not project positive returns sufficient to cover the required capital costs. The project therefore relies on NY Prize Phase III funding to achieve breakeven economics.

3.1.2 Benefits and Costs to Other Stakeholders

Prospective stakeholders in the Watervliet microgrid extend beyond the utility, City, and facilities to include other National Grid customers and residents of the surrounding areas of Watervliet. Direct benefits will accrue to the utility, the City, and connected facilities. The surrounding communities and larger state of New York will enjoy indirect benefits from the microgrid (further discussed in Section 5.2).

During an emergency power outage, the microgrid will maintain power to the connected facilities, including fire and safety and emergency shelter, all of which are accessible and available to residents across the City. The recreation center and church may serve as additional shelters, while maintaining power to dozens of residents will obviate the need for them to seek shelter.

New distributed energy resource assets will not defer any planned investments in generation or transmission and distribution (T&D) infrastructure. The proposed natural gas unit and solar array together possess a maximum generation capacity of 550 kW. This yields 450 kW of continuous load reduction for the larger National Grid grid from the natural gas unit (during both peak demand events and normal periods of operation) and 100 kW of variable support from the PV array.

Although no facilities currently possess backup generators that will be incorporated into the microgrid's generation mix, interconnecting additional backup generators will be possible in the future.

3.1.3 Purchasing Relationship

Due to the small scale of the project and low overall capital costs, the Project Team proposes National Grid own the generating assets as well as the microgrid infrastructure (including control equipment, distributed intelligent electronic devices, and new distribution lines). National Grid will inject the generated power into their distribution grid and continue to sell it to customers at prevailing rates through existing mechanisms. Due to the small size of the spinning asset and the utility ownership, the Project Team expects no participation in DR programs or paid ancillary services. Reserving capacity for participation is not economical because electricity sales provide more value to the project than do intermittent ancillary service payments from the New York Independent System Operator (NYISO). Figure 5 and Figure 6 provide visual representations of the purchasing relationship during normal and islanded operations.

Figure 5. Normal Operation Purchasing Relationship

The value streams and purchasing relationships between the various entities during normal operation.

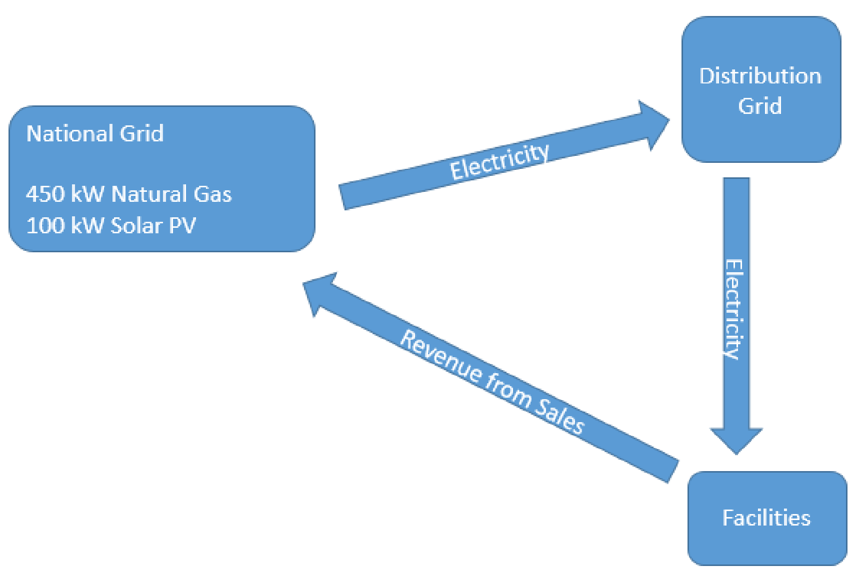
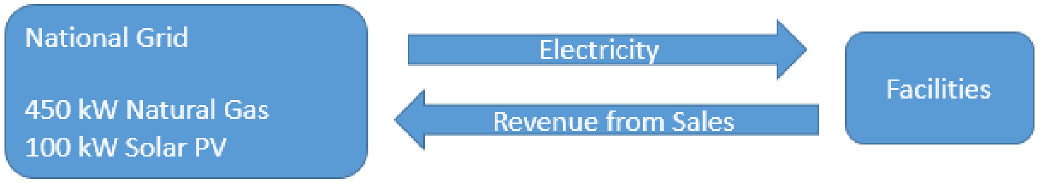


Figure 6. Islanded Operation Purchasing Relationship

Figure describes the value streams and purchasing relationships between the various entities during islanded operation.



3.1.4 Solicitation and Registration

The City and utility will work with identified facilities in Table 12 to participate in the project. This outreach will include informal discussions and, ultimately, signed agreements of participation in the microgrid. The tariff will remain as it is now given the proposed utility ownership of the project. Formal registration of facilities with the microgrid will be completed by the Project Team and virtually managed by programming the logic controllers to include or exclude the facility from islanded services based on their agreement with the utility. The Project Team views registration as an operational feature of the microgrid and not a legal requirement.

Electricity purchases by the customer facilities from National Grid will follow existing contractual and purchase relationships for both normal and islanded operation.

3.1.5 Energy Commodities

The microgrid's generation assets will produce electricity, but no thermal energy or paid ancillary services. Proposed generation assets include a 450 kW natural gas-fired unit and a 100 kW solar PV array, plus the existing 30 kW PV arrays at the Fire Station and Senior Center/Public Library. Together these DERs will provide up to 610 kW of electricity for the microgrid and the larger Watervliet community. National Grid will distribute the purchased electricity across its grid.

3.2 Commercial Viability – Value Proposition (Sub Task 3.2)

The microgrid will provide value to Watervliet, National Grid, direct participants, and the larger State of New York. The natural gas unit and solar array will reduce the City's reliance on higher-emission peaking assets during peak demand events and provide stable energy resources to critical and important facilities in emergency situations. National Grid will realize stable cash flows from the proposed energy generation resources. The benefits, costs, and total value of the microgrid project are discussed in detail below.

3.2.1 Business Model

Due to the small footprint of the proposed microgrid and the minimum capital requirements, Watervliet is well positioned to adopt a vertically integrated project wherein National Grid owns the proposed generation assets as well as the new and existing distribution and control infrastructure. All revenues and costs will accrue to National Grid, which will recoup the costs of generation through the sale of electricity across its existing customer base. This model provides the greatest benefits to Watervliet and most ably addresses the needs of the community. As a predominantly low and moderate income community and a relatively small project, it is well suited for utility ownership and operation of all components as a means to enhance energy resilience in a historically underserved community. The very low project returns suggest that disaggregating DERs from distribution and control infrastructure is not feasible, and full utility ownership in the low and moderate income context allows for a wider range of support from the state. As the owner and an entity with considerable utility expertise, National Grid will operate and retain responsibility for the day-to-day operation of the microgrid. There is little benefit from removing National Grid from an operational role in the microgrid.

Table 13 below provides an overview of the Watervliet microgrid project, including an analysis of project strengths, weaknesses, opportunities, and threats (SWOT).

Table 13. Watervliet Microgrid SWOT Analysis

A summary of the key strengths, weaknesses, opportunities, and threats (SWOT) associated with the Watervliet microgrid project.

Strengths	Weaknesses
• Evenly distributes cost burden so no single actor is responsible for the full project cost • Provides improved energy service and resilience to more than one hundred low and moderate income residents and, in doing so, aligns with one of the stated aims of REV • Leverages National Grid's expertise to facilitate load aggregation, following, voltage regulation, and other necessary daily operations in its capacity as owner/operator • Total capital cost is relatively low at only $1.62 M and may provide an attractive project for NY Prize or as a REV demonstration project	• Project ROI depends on the capital cost of microgrid infrastructure and may need NY Prize Phase III funding as well as additional support from the state • The small scale of generation disallows economics of scale and challenges overall project economics • Project cannot island for economic reasons as doing so would disrupt service to downstream loads
Opportunities	**Threats**
• Experiments with new methods of rate calculation, with the opportunity to revolutionize the role of utilities in electricity generation, distribution, and consumption in New York State • Integrates the local IOU with microgrid operation which may facilitate a smooth transition to a "grid of grids" and utilities as the distributed system platforms (DSPs) in the future • Demonstrates the feasibility of reducing load on the larger grid with distributed energy resources • Expands the microgrid to include additional critical facilities, low and moderate income residences, or perhaps the Watervliet Arsenal, which is adjacent to the project footprint	• Changes in regulatory requirements could impact the proposed business model and stakeholder goals—if the REV proceedings shift away from utility ownership of DERs in exceptional circumstances the proposed model will be untenable • If natural gas prices increase, it will significantly raise the microgrid's marginal cost of producing electricity

While there are several valuable strengths and opportunities associated with the vertical ownership model proposed within, there are also weaknesses and threats that must be addressed. These weaknesses are discussed below.

- **Financial** – The Watervliet microgrid proposal includes relatively small generation assets that are not of sufficient scale to return revenue sufficient to cover the capital investment. The proposed ownership by National Grid mitigates this weakness in two ways. First, the coupling of all revenue-bearing assets with the non-revenue bearing assets allows for the former to support the latter to the extent that revenue is available. The inability to island to economic reasons cannot be resolved without extensive modifications to the electrical infrastructure, and it is not clear that National Grid can or would desire to island a wholly owned and operated system for their own DR programs. Simply, project expansion to include more electrically adjacent facilities is feasible and would proceed at the discretion of National Grid as the owner/operator. In order to add additional, wholly-owned generation, National Grid would have to demonstrate to the NYPSC how it meets the established criteria.
- **Regulatory** – REV is unlikely to drastically shift away from exceptional circumstance utility ownership of generating assets. Such exceptions are governed by a set of criteria published in December 2014 and represent a major pillar of grid transformation in New York State and, therefore, are not likely subject to quick change. The very small size of generation, and the context as a NY Prize project, are likely sufficient to allow the utility to own the DERs without running afoul of the NYPSC.

3.2.2 Replicability and Scalability

The Watervliet microgrid is replicable and scalable model under certain conditions and is being designed with industry standard equipment and software that can be applied to diverse existing infrastructure.

Technical Replicability. The proposed microgrid technology does not present a barrier to project replicability. The primary components of the microgrid, including the proposed generation assets, switches, SCADA, and the EMS, are widely available and could be repeated in any given location. All interconnections with the National Grid grid are industry standard. Natural gas infrastructure is an essential component of the project's replicability; without a steady natural gas supply, other cities would have to sacrifice the reliability (by relying on solar or wind power) or emissions efficiency (by using diesel or fuel oil) that make this project feasible.

Organizational Replicability. The proposed business model relies on a determination from the New York PSC that National Grid may own and operate generation assets as part of the microgrid project. At present, there are several circumstances in which this may occur[19] and the project proposes to take advantage of the allowance for utility ownership in cases where a critical power reliability service is being provided to a community that would not otherwise receive the

[19] Case 14-M-0101, Dec. 12 2014, Appendix A.

service. Therefore, the organizational element of the Watervliet microgrid is restricted to a community or project that meets the published test. Moreover, the very small size of the generation and context of the project within NY Prize should assuage remaining NYPSC concerns of utility ownership of generation. Though this limits the propagation of vertically integrated IOU projects, there are numerous communities throughout the state, particularly low and moderate income communities, for which this may be the most viable path forward. As a NY Prize Phase III awardee, the Watervliet microgrid would provide a proof point for utility ownership and operation of small microgrids in low and moderate income communities.

Scalability. The microgrid is scalable to the limits of the facilities on adjacent portions of the Maplewood Station 307 feeder or to the limit of National Grid's appetite to connect proximate feeders in the area. The Watervliet microgrid does not rely on AMI meters to remotely disconnect loads that fall within the utility line breakers, meaning that any expansion will have to either consider the physical realities of partitioning new power lines from the larger grid or introduce AMI remote disconnect capability to all loads between utility line breakers. Additionally, because the proposed generation assets will operate at nearly full capacity throughout the year and there are no backup generators included in the design, new generation assets will be a prerequisite to expanding the microgrid in the future. Expansion provides an opportunity to add more critical facilities to the microgrid, including further municipal and important retail facilities, the Watervliet Arsenal, or additional low- and moderate-income housing units.

3.2.3 Benefits, Costs, and Value

The microgrid will provide both direct and indirect benefits to a wide range of stakeholders. National Grid will receive stable cash flows for the lifecycle of the project, the City and citizens will benefit from a more resilient electricity system, customers will see stabilized electricity prices, and the community will have access to municipal services and shelter during emergency grid outages. Preliminary analysis indicates cash flows from electricity sales will cover variable generation costs. However, depending on final infrastructure costs, project cash flows may not fully recover initial investment costs. In this case, the project's commercial feasibility will depend on NY Prize Phase III funding or other financial support. Projected costs and benefits are discussed in Table 14 through Table 18.

The customers will not bear any of the project's costs, and local residents will bear no costs unless the costs of the microgrid are rate-based at which point they may see a minimal increase in rates, if at all. Table 14 below provides an overview of the benefits and costs to National Grid, direct microgrid customers, citizens of Watervliet and surrounding municipalities, and the State of New York.

Table 14. Benefits, Costs, and Value Proposition to National Grid

The benefits, costs, and value proposition to National Grid as owner and operator of the system.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
National Grid	- The utility will receive the revenues from the operation of the DERs and sale of electricity - The utility will avoid total loss of revenues in emergency outage situations - Local generation reduces the amount of power that must be imported from the larger grid; this may defer future transmission & distribution investments - The utility will realize cost savings on decreased line congestion	- The utility will be responsible for the costs of constructing and operating the new DERs and control infrastructure - Maintenance of the new DERs	- The utility will enjoy improved grid resilience by integrating local generation assets with local distribution networks - The utility will gain experience and qualifications operating a microgrid in a low/moderate income community - National Grid will have a new supply of electricity that is valued at their average supply charge, but they will have a slightly reduced T&D charge in the area

Table 15. Benefits, Costs, and Value Proposition to the City of Watervliet

The benefits, costs, and value proposition to Watervliet.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
City of Watervliet	- The microgrid will provide a resilient and redundant energy supply to critical services - Meets NY State energy goals by encouraging DER construction and improving energy resilience - Municipal government facilities will be connected to the microgrid	- Watervliet is not anticipated to assume direct costs for this project	- Critical and important services will keep the lights on during outages, allowing Watervliet to be a point of relief for local citizens - The microgrid project will serve both municipal facilities as well as numerous low and moderate income residences, providing support for traditionally underserved communities - Generating electricity with solar PV arrays and a natural gas-fired unit will offset higher-emission peaking assets

Table 16. Benefits, Costs, and Value Proposition to Connected Facilities

The benefits, costs, and value proposition to connected facilities.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Connected Facilities	- Resilient and redundant energy supply to operations—power outages cost commercial and residential customers ~$40-60/kWh and ~$5-8/kWh, respectively[20] - Access to a local market for distributed energy generation makes investments in small DERs more attractive to connected facilities	- The connected facilities are not expected to incur any costs except for a marginally higher cost of electricity during islanded mode. This will not apply to the low and moderate income residences	- Maintain operations during emergency outages and provide valuable critical services to the Watervliet community - Supports upwards of 100 low and moderate income residential units that will not likely require shelter or additional services during a grid outage - Potential for partnerships and a local market for excess generation will encourage industrial stakeholders to build large-scale generation assets

Table 17. Benefits, Costs, and Value Proposition to the Larger Community

The benefits, costs, and value proposition to the larger community.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
Community at Large	- Access to a wide range of critical and important services during grid outages - Potential for inclusion if the microgrid footprint expands in the future	- Because the larger community will not be connected to the microgrid, this stakeholder group will not bear any significant costs	- Inclusion of critical and publically accessible facilities and shelter for times of emergency - Future expansion of the microgrid could bring more facilities into the design

Table 18. Benefits, Costs, and Value Proposition to New York State

Table describes the benefits, costs, and value proposition to New York State.

Beneficiary	Description of Benefits	Description of Costs	Value Proposition
New York State	- DERs will offset higher-emission peaking assets and diesel backup during peak demand events - Cash flows will provide tangible evidence of microgrid project's commercial viability - Indirect benefits (such as outages averted) will demonstrate the benefits of microgrids paired with DERs to citizens across the state and reduce load on the larger grid - Each microgrid accelerates NY State's transition from old macrogrid technologies to newer, smarter, smaller technologies	- Depending on financing plans, the growth of microgrid popularity, and increased use of natural gas-fired generators, the state may need to develop additional plans for expanding natural gas infrastructure	- Inclusion of traditionally underserved low and moderate income citizens - Successful construction and operation of a microgrid will demonstrate the tangible value of microgrid projects as investments - Indirect benefits associated with microgrids will encourage and inspire citizens to strive for DERs in their own communities

[20] PG&E; cited from http://www3.epa.gov/chp/basic/benefits.html.

3.2.4 Demonstration of State Policy and REV Concordance

The proposed microgrid coordinates with REV by providing a utility-maintained power distribution platform for locally owned DER assets. The ownership model has the potential to be extremely successful by establishing the local utility as the owner and operator of the system, bringing with it significant experience in energy generation and distribution.

The Project Team recognizes vertical integration of generation assets and transmission and distribution is not the preference of New York State except in exceptional circumstances. To date, these exceptions have been geared towards projects that support a critical power reliability need and for which non-utility investment has not been forthcoming. The Project Team believes that supporting a large collection of low- and moderate-income residents, in addition to the critical municipal facilities, is a worthy exception to standing policy and in concordance with the stated goals of REV.[21] The proposed microgrid provides an exceptional opportunity to construct a microgrid and improve statewide energy resilience while simultaneously extending energy services to a key New York State target group.

As more microgrids populate the region, National Grid is well positioned to serve as the distributed system platform (DSP) in its service territory to integrate multiple microgrids, aggregate excess generation capacity, and redistribute services to voltage or watt deficient microgrids, municipal grids, and load pockets. With a critical mass of microgrids or other individually managed load pockets, investor-owned utilities will be needed to constantly manage and balance the grid and will yield income on transmission, distribution and standby charges and the transactions necessary to facilitate such operation. Thus, more clearly articulated regulations will help the propagation of community microgrids while providing a role for utilities in ongoing management of this fundamentally new system of electricity management.

The microgrid presents an excellent opportunity to further expand future renewable energy generation and immediately improve the City's resilience to extreme weather events. Paired with energy efficiency programs, generation assets in Watervliet could shave a substantial electricity load from the larger grid during peak demand events when congestion costs are highest. Distributed renewable generation assets greatly improve resilience and reliability of local energy supply in extreme weather situations and encourage citizens within the community to invest in local energy generation and distribution. Watervliet's microgrid and DERs will immediately reduce the City's reliance on high-emission peaking assets during peak demand events and provide a platform for expanding the City's clean distributed energy resources capability in the future.

[21] NYPSC Case 14-M-0101, "Memorandum and Resolution on Demonstration Projects," Dec. 12, 2014, Appendix A.

3.3 Commercial Viability – Project Team (Sub Task 3.3)

The Project Team includes National Grid, the local Watervliet government, Booz Allen Hamilton, Siemens AG, and Power Analytics. It may expand to include financiers and legal advisors as the project develops. Details on the Project Team can be found in this section.

3.3.1 Stakeholder Engagement

The Project Team has been engaged and in constant communication with local stakeholders from the outset. Booz Allen and its partners in the City have also communicated with each of the proposed facilities to gauge electric and steam demand and discuss other aspects of the project development.

3.3.2 Project Team

The Watervliet microgrid project is a collaboration between the public sector, led by the City of Watervliet, and the private sector, led by National Grid and Booz Allen Hamilton with significant support from Power Analytics and Siemens. Each of the private sector partners is exceptionally well qualified in the energy and project management space, and the City of Watervliet has strong interest in improving its energy reliability and expanding its clean energy generation capacity. Tables 19 and 20 below provide information about the Project Team.

Table 19. Project Team

Background on Booz Allen Hamilton, Siemens AG, Power Analytics, and National Grid.

<table>
<tr><th>Booz Allen Hamilton</th><th>Headquarters: McLean, VA</th><th>Annual Revenue: $5.5 B</th><th>Employees: 22,700</th></tr>
<tr><td colspan="4">History and Product Portfolio: Booz Allen was founded in 1914. In the ten decades since its founding, Booz Allen has assisted a broad spectrum of government, industry, and not-for-profit clients including the American Red Cross, all branches of the Department of Defense, the Chrysler Corporation, NASA, and the Internal Revenue Service. Booz Allen’s energy business includes helping clients analyze and understand their energy use and develop energy strategies, recommending technology solutions to achieve their energy goals, and executing both self- and 3rd party funded projects including energy efficiency, renewable energy, and smart grids.</td></tr>
<tr><th>Siemens AG</th><th>Headquarters: Munich, Germany;
U.S. Headquarters: Washington, DC</th><th>Annual Revenue: €71.9 B</th><th>Employees: 343,000</th></tr>
<tr><td colspan="4">History and Product Portfolio: Siemens AG was founded in 1847 and is now one of the world’s largest technology companies. Siemens AG specializes in electronics and electrical engineering, operating in the industry, energy, healthcare, infrastructure, and cities sectors. Siemens AG develops and manufactures products, designs and installs complex systems and projects, and tailors a wide range of solutions for individual requirements. The Siemens Microgrid Team develops comprehensive solutions leveraging the strength of Siemens’ portfolio – from generation sources such as gas, wind, and solar, to transmission & distribution products, to control software solutions and services.</td></tr>
<tr><th>Power Analytics</th><th>Headquarters: San Diego, CA</th><th>Annual Revenue: $10 15M</th><th>Employees: 50</th></tr>
<tr><td colspan="4">History and Product Portfolio: Founded 25 years ago, Power Analytics is a privately-held small business that develops and supports electrical power system design, simulation, and analytics software. The Company’s worldwide operations include sales, distribution, and support offices located throughout North America, South America, Europe, Asia, and Africa and Australia.</td></tr>
<tr><th>National Grid</th><th>Headquarters: London, UK</th><th>Annual Revenue: £15.2 B</th><th>Employees: 23,909</th></tr>
<tr><td colspan="4">History and Product Portfolio: Founded in 1990, National Grid is an international electrical and gas company operating in the UK and northeastern US. National Grid provides electric service to approximately 3.4 million customers and gas service to approximately 3.6 million customers across the northeastern US. National Grid receives yearly operating revenues of approximately £15.2 billion.</td></tr>
</table>

Table 20. Project Team Roles and Responsibilities

Table outlines roles, responsibilities, and expectations for each member of the Project Team during development, construction, and operation of the microgrid.

Team Member	Roles and Responsibilities		
	Project Development	Construction	Operation
National Grid	National Grid will finance and own the DERs and infrastructure. The utility's expertise will be essential in planning microgrid construction, and the utility will be responsible for ongoing operation and maintenance (O&M) of the microgrid.	National Grid will finance and oversee construction of all microgrid components.	National Grid will operate and maintain the microgrid. This includes responsibility for switching to island mode and regulating voltage, frequency across the microgrid's loads in both grid-connected and island mode, and distribution of generated power.
City of Watervliet	The City will serve as the main conduit to representatives of the critical and important facilities and other interests in the City. This effort is spearheaded by the City Administrator, who is responsible for local outreach.	As the liaison, the City will coordinate with all local, regional, and state parties as required. They will be responsible for assisting with any local permitting and regulatory requirements.	As the liaison, the City will coordinate with all local, regional, and state parties as required.
Booz Allen	BAH is responsible for the delivery of the Feasibility Study and its component parts. This includes serving as the central clearinghouse of data, design, and proposal development as well as the key POC for NYSERDA on this task.	BAH will serve in an advisory and organizational role, working in a similar prime contractor capacity to provide overall design, costing, and construction management services.	BAH would serve in an outside, advisory capacity upon completion of the microgrid and during its operation.
Siemens	Siemens is the engineering and technology partner of this project. They will develop the technical design and system configuration in concert with BAH engineers and the Power Analytics team.	Siemens will have primary responsibility for the shovel-in-the-ground construction and installation of hardware and generation assets.	Ensuring proper functioning and maintenance of the microgrid technology components throughout.
Power Analytics	Power Analytics is the partner for energy software solutions. The PA team, in conjunction with Siemens and Booz Allen, is responsible for the design of the SCADA and system software components and controls.	Power Analytics will lead the installation of control and energy management software following hardware installation and in concert with Siemens.	Provide IT systems support; may play an active role in system management through the EnergyNet software platform.

Team Member	Roles and Responsibilities		
	Project Development	Construction	Operation
Suppliers	There are no suppliers required during this development phase, however project partners and suppliers Siemens and Power Analytics are closely involved in feasibility and design portions of the project. BAH is in touch with several additional suppliers of hardware and software including Duke Energy, Con Ed Solutions, Enel Green Power, Anbaric Transmission, Bloom, and Energize.	Siemens or another engineering and technology firm will be the hardware supplier, including switches and other physical controls. Power Analytics or another software company will be the EMS and SCADA provider, responsible for software and server components.	The installer of the hardware and software will continue to provide maintenance and advisory services as require to ensure proper and efficient functioning of their components. The software provider will work in cooperation with National Grid to assess the best approach to daily operations of the software system.
Financiers/Investors	Outside finance advisors will be available to assist National Grid, if necessary.	Outside financial advisors will be retained to assist, if necessary.	Outside financial advisors will be retained to assist with any issues in capital finance or repayment.
Legal/Regulatory Advisors	Regulatory advice is housed within Booz Allen. Further counsel will be retained as necessary to create the SPV and arrange financing.	Legal and regulatory will be a combination of Booz Allen, the Town, National Grid, and any outside counsel required.	Legal and regulatory will be the responsibility of the Town, the utility, and any investors in the SPV.

3.3.3 Financial Strength

The owner of the microgrid project will be National Grid. Moody's Investor Service rates National Grid at a Baa1 credit rating. According to the Moody's rating scale, "Obligations rated Baa are judged to be medium-grade and subject to moderate credit risk and as such may possess certain speculative characteristics." National Grid is an international electrical and gas company operating in the UK and northeastern US. The utility provides electric service to approximately 3.4 million customers and gas service to approximately 3.6 million customers across the northeastern US. National Grid receives yearly operating revenues of approximately $22.3 billion.

3.4 Commercial Viability – Creating and Delivering Value (Sub Task 3.4)

The specific technologies included in the microgrid design will enable rapid and efficient transitions between grid-connected and island mode based on signals from a Supervisory Control and Data Acquisition (SCADA) control center. The proven efficacy of proposed microgrid components enhances the replicability and scalability of the design. This section will discuss the technical components of the microgrid and why they were chosen.

3.4.1 Microgrid Technologies

The specific technologies included in the microgrid design were chosen to meet the goals of providing reliable and efficient power in both grid-connected and island mode, achieving automatic load following, and developing black-start capability.

A solar PV array and a natural gas unit were chosen as generator technologies to reduce greenhouse gas emissions and enhance the reliability of the power supply. The natural gas unit will be capable of automatic load following (responding to load fluctuations within cycles, allowing the microgrid to maintain system voltage and frequency), black starts, and adjusting generation output. The solar PV system will provide a renewable component to the microgrid generation mix and represents a more appropriate addition than an expanded natural gas unit. It will provide emission-free electricity during daylight hours and move Watervliet and New York State closer to the renewable generation goals set forth in the New York State Energy Plan. However, PV generation will face the same problems in Watervliet that it does elsewhere in the northeast United States: variable weather conditions and long periods of darkness in the winter.

The Watervliet microgrid includes numerous components that have been previously used and validated. Solar PV and natural gas generation are both widely used technologies, with more than 6 gigawatts (GWs) of solar PV installed in 2015 in the United States. The switch components are all industry standard and are widely used in utilities worldwide, and the Intelligent Electronic Devices, which are robust and safe via embedded electrical protections, are similarly standard across the industry. Siemens microgrid technologies are recognized worldwide for their flexibility, reliability, and expandability—successful examples of Siemens microgrid technology at work include the Parker Ranch and Savona University microgrids.[22] Team partner Power Analytics has similarly successful implementations of its Paladin software in microgrid environments, including the 42 MW, 45,000 person UC San Diego microgrid project.[23]

3.4.2 Operation

Investor-owned utilities generally prefer to operate systems integrated into their existing infrastructure. National Grid, as the project owner and operator, will facilitate smooth operation and transitions between islanded and grid parallel operation. The utility will be responsible for the continued and successful operation of the component pieces of the grid, including software, switches, servers, generation, and meters, but they will have ongoing assistance from the Booz Allen team as required. Regular maintenance and checks of equipment will be conducted based on manufacturer or installer recommendations and will ensure the proper function of all grid elements. Decisions as to the proper level of generation from local assets, load following, and other similar issues will be addressed automatically in real-time by the logic controllers and microgrid control system. The decision algorithms will be programmed upon installation with input from the utility and with the ability to alter or revise them if operations dictate that to be the appropriate action. Interactions with the National Grid grid will be governed by the microgrid controllers.

The facilities will continue to be billed for electricity via the regular National Grid billing mechanism and cycle. National Grid's revenue will be sufficient to cover the cost of production of the DERs.

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[22] Siemens case studies; available from http://w3.usa.siemens.com/smartgrid/us/en/microgrid/pages/microgrids.aspx.

[23] http://www.poweranalytics.com/company/pdf/M-12-GE-PPT-X-001-03%202012%20UCSD%20Virtual%20summit.pdf.

3.4.3 Barriers to Completion

The barriers to constructing and operating the microgrid are primarily financial. The high capital costs and relatively long payback make the investment a difficult one. The DERs should provide positive operating income for National Grid; however, the revenues will not be able to fully recover capital expenditures in the absence of NY Prize Phase III. Further, the Watervliet microgrid will not be capable of entering island mode to participate DR programs and therefore cannot capture any economic benefit from doing so.

The other predominant barrier is approval of utility ownership. While the Project Team believes that serving a low-income population where additional programs could be rolled out to a small pilot footprint makes this project a great REV demonstration but also should prove appealing to the utility as well due to the low capital investment required.

3.4.4 Permitting

The Watervliet microgrid may require certain permits and permissions depending on the ultimate design choices. Distributed energy resource assets will require zoning variances or approvals as accessory uses because they are currently not permitted on hospital property. Watervliet is not in any EPA criteria pollutant nonattainment zones; however, the natural gas unit may require air quality permits pursuant to the Clean Air Act.

3.5 Financial Viability (Sub Task 3.5)

The distributed energy resource assets included in the microgrid design will produce revenue streams from electricity sales to existing National Grid customers. These assets will require significant initial capital outlays as well as annual operation and maintenance costs. The Project Team expects that microgrid infrastructure in Watervliet will require considerable investment and will play a major role in final project economics. National Grid may be eligible for incentives related to small solar installations that will offset a portion of the cost; however, none are available for non-CHP natural gas generation.

3.5.1 Revenue, Cost, and Profitability

The microgrid has a number of savings and revenue streams, as outlined in Table 21. The revenues will sum to approximately $250,000 per year, which will exceed the yearly generation costs (estimated to be approximately $225,000 per year). The project will rely heavily on NY Prize Phase III funding to support capital investments. See Table 21 for the savings and revenues and Table 22 for the capital and operating costs.

Table 21. Savings and Revenues

Expected revenues and savings directly associated with operation of the microgrid and its DERs.

Description of Savings and Revenues	Savings or Revenue	Relative Magnitude	Fixed or variable
Electricity sales from 450 kW natural gas system	Revenue	~$240,000/yr	Variable
Electricity sales from 100 kW solar PV	Revenue	~$10,000/yr	Variable
Total Revenue		**$250,000/yr**	Variable

Table 22. Capital and Operating Costs

Table describes the expected costs from construction and operation of the microgrid.

Description of Costs	CapEx or OpEx	Relative Magnitude	Fixed or Variable
450 kW Natural Gas Gen.	Capital	~$585,000	Fixed
100 kW Solar PV Array	Capital	~$240,000	Fixed
Microgrid Control Systems	Capital	~$450,000	Fixed
Distributed Equipment	Capital	~$45,000	Fixed
IT Equipment (Wireless stations and cabling)	Capital	~$50,000	Fixed
New Distribution Lines[24]	Capital	$30,000	Fixed
Total CapEx		**$1,400,000**	Fixed
Design considerations and simulation analysis	Planning and Design	$750,000	Fixed
Project valuation and investment planning	Planning and Design	$100,000	Fixed
Assessment of regulatory, legal, and financial viability	Planning and Design	$75,000	Fixed
Development of contractual relationships	Planning and Design	$75,000	Fixed
Total Planning and Design		**$1,000,000**	Fixed
450 kW Natural Gas Fuel	Operating	~$110,000/yr	Variable
450 kW Natural Gas Maintenance	Operating	~$45,000/yr	Variable
100 kW Solar PV Maintenance	Operating	~$2,000/yr	Fixed
Microgrid Controls O&M	Operating	~$70,000/yr	Fixed
Total OpEx		**$225,000**	Variable

The proposed microgrid may qualify for a single incentive program in the Federal solar ITC. Other possible sources of incentive revenue include NYSERDA Phase III NY Prize funding (up to $5 million, but will not exceed 50% of capital costs) and other NYSERDA programs related to low and moderate income community energy investments. See Table 23 for a list of available incentive programs.

[24] Based on per foot new line construction costs.

Table 23. Available Incentive Programs

State and utility incentive programs that were included in the commercial/financial feasibility analysis and whether the incentive is required or preferred for the microgrid project to be feasible.

Incentive Program	Value	Required or Preferred
NYSERDA NY Prize Phase II	~$1,000,000	Required
NYSERDA NY Prize Phase III	~$5,000,000	Required
Federal ITC	~$70,000	Preferred. Eligibility not assured

3.5.2 Financing Structure

Awards from Phase II of the NY Prize Community Microgrid Competition will supply most of the funding for project design and development, with community and outside financing providing the required 25% cost share. The City of Watervliet and their Project Team will provide needed in-kind services consisting primarily of system expertise and support. Development will conclude with formal contract relationships between the utility and the customers of the microgrid, available and relevant rate and tariff information from the NYPSC, and firm financing for the construction of the project (described below).

National Grid will leverage Phase III funding from NYSERDA to complete the construction phase and will supplement with corporate bonds or cash equity. Phase III NY Prize funding, which will provide up to $5 million per project for the purchase and installation of microgrid and DER equipment. The grant would cover 50% of the total required capital, for Watervliet this total is over $800,000. Any bond offering from National Grid will be backed by the revenues of this project as well as the full weight of National Grid's electric transmission and distribution interests. Absent Phase III NY Prize funding, the project is not expected to generate sufficient cash flow to recover capital investments; however, National Grid could also pursue this project as a demonstration project by more actively incorporating the low-income residents.

3.6 Legal Viability (Sub Task 3.6)

Like any infrastructure project that involves the development of public and private land, the Watervliet microgrid project will require legal and regulatory agreements for ownership, access, zoning, permitting, and regulation/oversight. This section considers the various legal aspects of the microgrid project and discusses the likelihood of each becoming an obstacle to the project's success.

3.6.1 Ownership and Access

Legal considerations will include access limitations, franchising, zoning, and permitting. National Grid will own and operate the proposed DERs and microgrid infrastructure. Microgrid equipment will be installed on City or utility-owned land, while generators will be on City land (natural gas at the Senior Center) and on private property (PV at Hudson Shores Plaza). Property rights and access limitations should not be a concern for microgrid infrastructure, but National

Grid and Hudson Shores Plaza will need to formalize an access agreement for the roof mounted PV. The data network that supports the microgrid logic units and controllers is owned by the City of Watervliet—access to this network will not represent a significant barrier to project completion.

3.6.2 Regulatory Considerations

State and Utility Regulation

The NYPSC will continue to treat National Grid as an electric corporation and this project as a component of their regular operations. As such, all electricity tariffs will remain subject to NYPSC approval and any changes will need to follow the established rate filing procedures.

Current state policy does not support vertically integrated utilities; however, the exceptionally small size of the proposed generation, coupled with the demonstration aspect of the project, should allow dispensation for utility ownership of generation. A ruling from the NYPSC allowing the proposed ownership structure will be affirmatively sought before construction commences.

Local Regulation

All entities that require the use of public ways (i.e., for transmission or distribution facilities) must be granted permission by the presiding municipal authority in the form of a franchise or some lesser consent, depending on the scope of the usage. The cities and villages of New York have specific statutory authority to grant franchises. The vast majority of the distribution infrastructure required to complete this proposal is already in place; the design requires only a short distance of new lines that will need approval. The Project Team expects no challenges obtaining the required approval.

Primary electric generation is not currently a permitted use in any of the relevant zoning districts in Watervliet, and siting the natural gas generator would require either an exemption as an accessory use or a zoning variance. The authority for each resides with the City Zoning Board of Appeals; however, there is no clear path to either an accessory use determination or a zoning variance. Rooftop solar at Hudson Shores should not pose a significant problem because it is several stories above street level and on private property. The Project Team expects building and safety permits will be required. The natural gas unit will be sited on municipal land and will primarily benefit municipal facilities. Therefore, any required variances or accessory use determinations should not be problematic.

Air Quality

Natural gas generators may be subject to a variety of federal permits and emission standards depending on the type of engine, the heat or electrical output of the system, the amount of electricity delivered to the grid versus used on-site, and the date of construction. The specific details associated with the proposed natural gas in Watervliet will determine the applicability of the regulations below. Clean Air Act regulations applicable to Reciprocating Internal Combustion Engine systems will apply. These regulations include:

- National Emission Standards for Hazardous Air Pollutants (NESHAP) for Stationary Reciprocating Internal Combustion Engines (RICE): 40 CFR part 63 subpart ZZZZ
- New Source Performance Standards (NSPS) for Stationary Compression Ignition (CI) Internal Combustion Engines (ICE): 40 CFR part 60 subpart IIII
- NSPS for Stationary Spark Ignition (SI) ICE: 40 CFR part 60 subpart JJJJ

Per EPA guidance, these regulations apply to all engine sizes, regardless of the end use of the power generated. However, further review and analysis must be conducted when details of the type and size of the generation system are confirmed.

New York state has enacted amendments to Environmental Conservation Law Articles 19 (Air Pollution Control) and 70 (Uniform Procedures), and Department of Environmental Conservation (DEC) amended regulations 6NYCRR Parts, per the 1990 Amendments to the Clean Air Act. With this demonstration of authority, DEC received delegation of the Title V operating permit program from the US Environmental Protection Agency (EPA). Title V Permits are required for all facilities with air emissions greater than major stationary source thresholds, which this project will not exceed. New York's air pollution control permitting program combines the federal air operating permitting program with long-standing features of the state program. The primary rules for applications are found in 6NYCRR:

- 200 (General Provisions)
- 201 (Permits and Certificates)
- 621 (Uniform Procedures)
- 231 (New Source Review in Non-attainment Areas and Ozone Transport Regions)

Final application of these rules will depend on the size and technology of the selected natural gas unit.

3.7 Project Commercial and Financial Viability Conclusions

The Watervliet microgrid design includes ten facilities including two groups of low/moderate income residences, the Police Station/City Hall, the Fire Station, a recreation center and a civic center (Red Cross certified shelter), the Senior Center/Public Library, the Public Works Department, United Methodist Church, and the Hudson Shores Plaza apartments. A 450 kW natural gas reciprocating engine will be sited at the Senior Center/Public Library and a 100 kW solar PV array will be sited at Hudson Shores Plaza, which provides sufficient rooftop space for the PV. In addition, there are 30 kW solar PV arrays at the Senior Center/Public Library and at the Fire Station. The existing PV arrays will provide power to the microgrid; however, due to their small inverter based loads, they will not be controlled by the MCS. The project will operate under an ownership model in which the local utility, National Grid, will own and operate the project. While vertical integration of generation and transmission and distribution is generally not allowed in NY State, the Project Team believes both the very small size of the generation and the low income demonstration potential of the project will provide for an ownership exception.

The proposed microgrid's commercial feasibility may depend on NY Prize Phase III funding. The Project Team forecasts yearly revenues of approximately $250,000 from the generators, which should reliably cover yearly system operation and maintenance costs (forecasted to be approximately $225,000 per year). Revenue from generator operation will not be sufficient to recover the capital cost, so the project will require extra subsidies (i.e., NYSERDA NY Prize funding) to fully recover initial investment costs. Absent or in conjunction with further NY Prize funding, the Watervliet microgrid proposal is well suited to receive support under NYSERDA and NY DSP programs targeting the expansion of energy services and resilience in low and moderate income communities.

In addition to revenues from electricity sales, the microgrid will provide indirect financial and non-financial benefits to community members, the City of Watervliet, and National Grid. Improved energy resilience enhances the local population's safety and quality of life during emergency outages, and local energy generation reduces the strain on the larger energy transmission and distribution infrastructure. Future expansion of the microgrid could maintain electric service to more facilities in Watervliet, providing citizens with access to pharmacies, gas, and groceries in outage situations. Moreover, the inclusion of dozens of low and moderate income residences supports state energy goals and the social good.

Permitting and regulatory challenges should be reasonably straightforward. The primary regulatory hurdles will be obtaining permits for the natural gas unit under the Clean Air Act and obtaining zoning permission for the siting of the generation.

4. Cost Benefit Analysis

Section 4 Cost Benefit Analysis is made up of seven sections in addition to the introduction:

- ***Section 4.1*** analyzes the *facilities connected to the microgrid* and their energy needs.
- ***Section 4.2*** discusses the *attributes of existing and proposed DERs*, including factors such as nameplate capacity and expected annual energy production.
- ***Section 4.3*** analyzes *potential ancillary services sales and the value of deferring transmission capacity investments*.
- ***Section 4.4*** reviews the *overall costs* associated with construction and installation of the microgrid as well as the fuel, operation, and maintenance costs required over the lifetime of the microgrid.
- ***Sections 4.5 and 4.6*** discuss the *community benefits* of maintaining power during a grid-wide outage and outline the costs associated with operating the microgrid in island mode.
- ***Section 4.7*** presents the Industrial Economics (IEc) *benefit-cost analysis report and associated Project Team commentary.*

4.1 Facility and Customer Description (Sub Task 4.1)

The Watervliet microgrid will include ten facilities from various rate classes and economic sectors. NYSERDA designates three primary rate classes based on type of facility and annual electricity consumption: residential, small commercial (less than 50 MWh per year), and large commercial (greater than 50 MWh per year). See Table 24 for basic statistics on each facility's energy usage. Five of the ten microgrid facilities belong to the large commercial rate class requiring approximately 729 MWh of electricity per year. Two facilities belong to the small commercial rate class and use approximately 67 MWh per year. An additional three facilities belong to the residential rate class and use approximately 1,961 MWh per year. Additionally the average aggregate demand of all ten facilities in 2014 was 0.314 MW and rose as high as 0.673 MW.[25]

There are three kinds of facilities in the microgrid: public, residential and religious. The public facilities include the police station, city hall, the fire station, Memorial Recreation center, a senior citizen center, the public library, and the public work department. These facilities total to 21% of the microgrid's total annual electricity usage. The residential facilities are the Hudson Shores Plaza and two other residential groups; they make up the 71% of the facility electricity usage. The religious facility, the United Methodist Church, comprises 8% of the annual electricity usage.

The combination of existing and proposed generation assets included in the microgrid design will be capable of meeting 100% of average aggregate facility energy usage during a major power outage, but may approach their generation limits if several large facilities simultaneously reach peak energy use. For information on each facility's average daily operation during a major power outage, see Table 24.

[25] 0.722 MW is non-coincident peak demand, while 0.673 MW is coincident peak demand.

Table 24. Facility and Customer Detail Benefit[26]

Table provides details about each facility and customer served by the microgrid, including average annual electricity usage, 2014 peak electricity demand, and hours of electricity required during a major power outage.

REDACTED PER NDA WITH NATIONAL GRID

[26] Load data was provided to Booz Allen by National Grid.

4.2 Characterization of Distributed Energy Resource (Sub Task 4.2)

The microgrid design incorporates distributed energy resources, including two existing solar PV arrays, one proposed natural gas generator, and one proposed solar PV array. The proposed natural gas unit and solar PV arrays (both proposed and existing) will produce an average of 0.405 MW of electricity throughout the year including projected capacity factors.[27]

The natural gas generator has a nameplate capacity of 0.45 MW and will operate nearly continuously. Assuming a capacity factor of 85%, the natural gas unit will produce approximately 3,350 MWh of electricity over the course of the year. If a major power outage occurs, the natural gas unit will produce an average of 9.18 MWh of electricity per day, which would provide over 100% of the microgrid's average daily demand. The natural gas units use around 9.5 Mcf (1000 ft^3) of natural gas per MWh generated, which amounts to a fuel cost of around $34/MWh to operate.[28]

Limited by weather conditions and natural day-night cycles, the two 0.03 MW and 0.1 MW solar PV arrays are expected to produce a combined 196 MWh per year (assuming a capacity factor of 14%). Because many outages are caused by severe weather events, solar panels cannot be relied upon to provide energy during emergency outages without supplementary battery storage. However, on average the solar arrays will produce a combined 0.54 MWh of electricity per day, which represents 7% of average daily electricity demand from microgrid-connected facilities. Maintenance costs for the solar array will be around $3,200 per year,[29] which means the marginal cost of producing solar electricity will be about $34/MWh.[30]

See Table 25 for a detailed list of all proposed and existing distributed energy resources in Watervliet.

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[27] NG generator capacity factor: 85% (EPA estimate for 10 MW generator, http://www3.epa.gov/chp/documents/faq.pdf)
Solar array capacity factor: 14% (NREL PV Watts Calculator).

[28] Price of natural gas: $3.62 per Mcf (average National Grid supply price from 2013-2015).

[29] Annual fixed O&M cost: $20/kW per year (NREL, http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html).

[30] Capital cost: $2,400/kw (Siemens estimate).
Variable cost: 30 years of production at a cost of $20/kW per year (Siemens lifecycle estimate, NREL).
Discount rate: 7% (industry standard discount rate; NREL http://www.nrel.gov/docs/fy13osti/58315.pdf).

Table 25. Distributed Energy Resources

Table lists DERs incorporated in the microgrid, including their energy/fuel source, nameplate capacity, estimated average annual production under normal operating conditions, average daily production in the event of a major power outage, and fuel consumption per MWh generated (for fuel-based DERs).

Distributed Energy Resource Name	Location	Energy Source	Nameplate Capacity (MW)	Average Annual Production Under Normal Conditions (MWh)	Expected Daily Production During Major Power Outage (MWh)	Potential Daily Production During Major Power Outage (MWh)	Fuel Consumption per MWh	
							System fuel	Units of MMBTUs
DER1 – Proposed Natural Gas Generator	Senior Center/Public Library	Natural Gas	0.45	3,350.7	9.18	10.8	9.26 Mcf	9.5 MMBTUs
DER2 - Existing Solar Panel	Senior Center/Public Library	Sunlight	0.03	36.8	0.10	0.24[31]	N/A	N/A
DER3 - Existing Solar Panel	Fire Station	Sunlight	0.03	36.8	0.10	0.24	N/A	N/A
DER4 - Proposed Solar Panel	Hudson Shores Plaza	Sunlight	0.1	122.6	0.34	0.8	N/A	N/A

[31] Assumes 10 hours of production (daylight) at 80% of capacity.

4.3 Capacity Impacts and Ancillary Services (Sub Task 4.3)

4.3.1 Peak Load Support

The microgrid's proposed generation assets will operate nearly continuously throughout the year, providing a constant level of load support. Although continuous operation will limit the natural gas generator's ramp-up capability during peak demand events, it will also maximize revenue for owner of the microgrid. See Table 26 for the maximum generation capacities of the proposed and existing DERs.

The proposed solar arrays will be at their most productive on days with peak solar irradiance when peak demand events are common, thus providing peak load support when it is most needed. They will provide around 0.0224 MW of load support on average over the course of a year. However, their generation depends on weather conditions and time of day, therefore solar arrays are not a reliable source of peak load support.

Table 26. Distributed Energy Resource Peak Load Support

Table shows the available capacity and impact of the expected provision of peak load support from each DER.

Distributed Energy Resource Name	Location	Available Capacity (MW)	Does distributed energy resource currently provide peak load support?
DER1 – Proposed Natural Gas Generator	Senior Center/Public Library	Maximum of 0.45	No
DER2 - Existing Solar Panel	Senior Center/Public Library	Maximum of 0.03	Yes
DER3 - Existing Solar Panel	Fire Station	Maximum of 0.03	Yes
DER4 - Proposed Solar Panel	Hudson Shores Plaza	Maximum of 0.1	No

4.3.2 Demand Response

DR programs require facilities to curtail load or expand generation using generators or battery storage in response to forecasted or real-time peak demand events on the larger grid. Additional detail outlining the viability of participating in DR programs can be found above in Section 2.2.22.

4.3.3 Deferral of Transmission/Distribution Requirements

The 0.405 MW of average local generation produced by the DERs will slightly reduce the amount of electricity imported from the larger NYISO and National Grid power lines, which may defer the need to invest in new or upgraded power lines. Although these power lines will last up to one hundred years if well maintained,[32] they can only transmit a limited amount of power. As demand for electricity in Watervliet increases, the lines might need to be supplemented to handle additional load.

[32] Professor John Kassakian, MIT: http://engineering.mit.edu/ask/how-do-electricity-transmission-lines-withstand-lifetime-exposure-elements.

The same is true for distribution capacity investments on a local, feeder-by-feeder basis. However, constructing DERs could actually increase the distribution capacity investment cost in certain cases (e.g., if the assets are placed in remote locations and thus expensive to connect to the local grid). Although Watervliet has ample capacity within the town, approximately 600 feet of new distribution lines will be need to be built to properly connect the microgrid facilities on different feeders and will require a significant distribution capacity investment.

4.3.4 Ancillary Service

None of the existing and proposed generation resources in Watervliet will participate in ancillary services markets. Although the natural gas generator can change output quickly enough to qualify for some paid NYISO ancillary service programs, it will not have sufficient capacity to participate. Most paid NYISO ancillary service programs require at least 1 MW of output regulation, which represents over double of the natural gas generator's maximum output.

Although the natural gas generator unit will not participate in paid NYISO ancillary service programs, it will provide many of the same ancillary services to the local Watervliet grid. For example, the natural gas generator will provide frequency regulation as a by-product of its operation. The Watervliet microgrid connected facilities will receive the benefits from provided ancillary services, but these will not be paid services and will not generate any new revenue streams—no services are being bought or sold. Instead, provision of ancillary services will represent a direct value to microgrid connected facilities.

4.3.5 Development of a Combined Heat and Power System

Due to lack of steam off-takers within a technically feasible distance of the generation site, the Project Team decided to use a natural gas generator instead of a combined head and power unit. Therefore there is no proposed CHP unit for the Watervliet microgrid.

4.3.6 Environmental Regulation for Emission

The microgrid's generation assets will drive a net 580 $MTCO_2e$ (metric tons CO_2 equivalent) increase in GHG emissions in Watervliet as compared to the New York State energy asset mix. The proposed natural gas unit will emit approximately 1,935 $MTCO_2e$ per year, [33] while the solar arrays will emit none. The current New York State energy asset mix would emit approximately 1,354 $MTCO_2e$ to produce the same amount of electricity[34]. The microgrid's generation assets will therefore result in a net increase in emissions by 580 $MTCO_2e$.

The microgrid's generation assets will not need to purchase emissions permits to operate and will not exceed current New York State emissions limits for generators of their size. The New York State overall emissions limit was 64.3 $MMTCO_2e$ in 2014, and will begin decreasing in the near future. The state sells an "allowance" for each ton of CO_2e emitted in excess of the limit at

[33] NG generator Emissions Rate: 0.51 $MTCO_2e$/MWh (assuming 117 lb CO_2e per MMBTU; EIA, http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11).

[34] Assuming an asset mix of 15% coal, 31% natural gas, 6% oil, 17% hydro, 29% nuclear, 1 % wind, 1% sustainably managed biomass, and 1% "other fuel". This adds up to around 0.36 $MTCO_2e$/MWh. Info from EPA (http://www3.epa.gov/statelocalclimate/documents/pdf/background_paper_3-31-2011.pdf).

allowance auctions, but does not require assets under 25 MW to purchase allowances. The natural gas unit is defined as a "small boiler" by NYS Department of Environmental Conservation (NYS DEC) limits (fuel input of 10-25 MMBTU/hour). The NYS DEC is currently developing output-based emissions limits for distributed energy resource assets. These limits on SO_2, NO_x, and particulate matter (to be captured in 6 NYCRR Part 222) should be published in late 2015 or early 2016. The main source of emissions regulations for small boilers is currently the EPA 40 CFR part 60, subpart JJJJJ—however, this law does not include gas-fired boilers.

The natural gas generator will require an operating permit in addition to other construction permits. The costs of obtaining this permit will be in line with the cost of a construction permit and not comparable to the price of emissions allowances.

Table 27 catalogs the CO_2, SO_2, NO_x, and Particulate Matter (PM) emissions rates for the natural gas generator.

Table 27. Emission Rates

Table shows the emission rates for each DER per MWh and per year. Notice the rates vary drastically for each emissions type (CO_2, SO_2, NO_x).

Distributed Energy Resource Name	Location	Emissions Type	Emissions Per MWh (Metric Tons/MWh)
DER1 – Proposed Natural Gas Generator	Senior Center/Public Library	CO_2	0.553
		SO_2	0.0000067[35]
		NO_x	0.00055[36]

4.4 Project Costs (Sub Task 4.4)

4.4.1 Project Capital Cost

The microgrid design requires the following new pieces of equipment at the substation and across the rest of the microgrid:

- A control system to provide one point of control for operating the microgrid and synthesizing real-time electricity data from the connected facilities.
- Intelligent Electronic Devices to interface with the 44 kV utility breaker at the substation as well as the smaller 13.2 kV distribution feeders.
- Automated breakers installed throughout Watervliet to allow the microgrid to isolate and maintain power to the microgrid connected facilities.
- Grid-paralleling switchgear to synchronize each generator's output to the system's frequency.

[35] Emissions calculator, EPA.
[36] EPA, http://www3.epa.gov/chp/documents/faq.pdf.

The total installed capital cost of the distribution equipment is estimated to be $465,500, and $10,000 for the IT infrastructure. The additional cost for overhead powerline installation will be $30,000. The cost if the powerlines are installed underground is $324,000.[37]The Project Team estimates the 0.1 solar PV arrays and 0.45 MW natural gas unit carry an installed costs of $240,000 and $585,000, respectively.[38] This brings the total installed capital cost to approximately $1.33 million if the powerlines are installed overhead, not including interconnection fees and site surveys. If the powerlines are installed underground the total capital costs will be $1.62 million. Additionally, the estimated capital cost does not account for any financial incentives or tax credits that may lower the overall cost of the microgrid. See Tables 28 and 29 below for estimated installed costs for each microgrid component.

The Project Team estimates nearly every piece of microgrid equipment has a useful lifespan of 20 years. The only component with a shorter lifespan will be the microgrid control system (Siemens SICAM PAS or equivalent), which will be replaced by more advanced software after seven to eight years.

Table 28 details capital cost of distributed equipment including the microgrid control system and centralized generation controls that will allow the operator and electronic controllers to manage the entire microgrid.

Table 28. Distributed Equipment Capital Cost

Table displays the estimated costs and lifespan of the distributed equipment associated with the microgrid.

Distributed Equipment Capital Costs				
Capital Component	**Quantity**	**Installed Cost ($) (+/ 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
Microgrid Control System	1 Primary	$50,000	7 - 8	Control system responsible for operating the microgrid sequencing and data concentration under all operating modes.
(Siemens SICAM PAS or equivalent)	1 Back-up			
Microgrid Control Center (Siemens MGMS or equivalent)	1	$300,000	20	Provides data trending, forecasting, and advanced control of generation, loads and AMI/SCADA interface, interface to NYISO for potential economic dispatch.
Automated Pole Mount Circuit Breaker/Switch (Siemens 7SC80 relay)	3 Upgrade 1 New	$15,000 $25,000	20	Upgraded breakers/switches at 2 overhead distribution switches. These switches isolate downstream loads from the microgrid. One new switch at Hudson Shores Plaza will allow load shedding in island mode.

[37] Cost estimate prorated from cost estimates provided by Consolidated Edison.
[38] Natural Gas Generator Capital Cost: $1,300/kW (Siemens Natural Gas estimate).
Solar PV Capital Cost: $2,400/kw (Siemens Solar PV estimate).

Distributed Equipment Capital Costs				
Capital Component	**Quantity**	**Installed Cost ($) (+/ 30%)**	**Component Lifespan (Years)**	**Purpose/Functionality**
Automated Underground Circuit Breaker/Switch (Siemens 7SJ85 relay or equivalent)	1	$10,000	20	Upgraded breaker at SW1. Disconnects the microgrid from primary feeder.
Generation Controls (OEM CAT, Cummins, etc.) (Load Sharing via Basler, etc.)	1	$4,000	20	Serves as the primary resource for coordinating the paralleling load matching and load sharing of the reciprocating generator.
PV Inverter Controller (OEM Fronius or equivalent)	1	$4,000	20	Controls PV output and sends data to MCS for forecasting.
WiMax Base Station	1	$8,000	20	Located near microgrid control cabinet. Communicates wirelessly with WiMax subscriber units for remote control and monitoring of breakers and switches. Should be installed at high location.
WiMax Subscriber Units	5	$10,000	20	Each subscriber unit can communicate back to the WiMax base station for SCADA monitoring and control or remote relay to relay GOOSE messaging.
WiMax configuration and testing	1	$22,000	-	The configuration and testing of the WiMax hardware
Installation Costs	-	$17,500	-	Installation of capital components in the microgrid

Table 29. Capital Cost of Proposed Generation Units

Table displays the estimated costs and lifespan of the equipment associated with the generation units of the microgrid.

Proposed Generation Units				
Capital Component	Quantity	Installed Cost ($) (+/ 30%)	Component Lifespan (Years)	Purpose/Functionality
0.1 MW PV System	1	$240,000	30	Generation of electricity
0.45 MW Natural Gas Unit	1	$585,000	20	Generation of electricity

The microgrid IT infrastructure will also require Cat-5e Ethernet cables for communication between distribution switches, generation switchgear, PV inverters, and network switches. The design uses Cat-5e cabling, including RJ-45 connectors at $0.61 per cable. 39 The total installation cost of cabling is approximately $5.65 per foot.[40] The Project Team will use the existing cabling infrastructure to install the communications cables, thereby avoiding the high costs of trenching the proposed lines. The estimated total cost for the microgrid IT infrastructure is around $10,000.[41]

In addition to the microgrid IT infrastructure, the microgrid will need new distribution lines in order to connect the DERs to the microgrid supported facilities. The Project Team has determined the approximate cost of building these new lines is $30,000 for an overhead installation and $324,000 for an underground installation.[42]

4.4.2 Initial Planning and Design Cost

The initial planning and design of the microgrid includes four preparation activities and total to approximately $500,000.

1. The first set of activities are the design considerations and simulation analysis which will cost approximately $375,000 to complete.
2. The second activity focuses on the financial aspects of the project including project valuation and investment planning which will cost approximately $75,000.
3. The third activity focuses on the legal aspects of the project including an assessment of regulatory issues and legal viability which will cost approximately $25,000.
4. The fourth activity focuses on the development of contractual relationships with key partners will cost approximately $25,000.

A breakout of the initial planning and design costs are illustrated in Table 30 below.

39 Commercially available RJ-45 connectors, $0.30 per connector.

40 Installation costs for Cat5e: $5.45/ft. Component cost for Cat5e: $0.14/ft (commercially available).

41 The Project Team estimated ~1,770 feet of Cat5e.

42 The Project Team has determined that approximately 600 feet of new line is required at the cost of $49/ft for overheard installation and $540/ft for underground installation according to Consolidated Edison estimates.

Table 30. Initial Planning and Design Cost

Table displays estimates and descriptions for engineering, legal, and financing costs involved in initial planning and design of the microgrid.

Initial Planning and Design Costs ($)[43]	Cost Components
$375,000	Design considerations and simulation analysis
$75,000	Project valuation and investment planning
$25,000	Assessment of regulatory, legal, and financial viability
$25,000	Development of contractual relationships
$500,000	**Total Planning and Design Costs**

4.4.3 Operations and Maintenance Cost

The proposed DERs will incur fixed operation and maintenance costs, including fixed annual service contracts.

Annual service for the solar array will cost approximately $3,200.[44] The microgrid owner will also incur $47,000/year in costs for annual fixed system service agreements for the proposed natural gas generator. [45]

The DERs will also incur variable O&M costs that fluctuate based on output. These include fuel and maintenance costs outside of scheduled annual servicing. First, the natural gas generator will require capital for fuel, consumable chemicals, and other operating expenses. The average price of natural gas for the microgrid will be $3.62/Mcf, which translates to an average fuel cost of $34/kWh for the natural gas unit.

The solar PV arrays will not require fuel to operate, and it should not require service outside of the normally scheduled downtime. Normally scheduled downtime should cost approximately $20/kW per year.[46]

Annual service for all non-DER microgrid components will cost approximately $70,000 per year.[47] Table 31 outlines all fixed operations and maintenance (O&M) costs associated with normal operation of the DERs.

[43] Estimates developed by Booz Allen Project Team and independent consultant.
[44] Annual service for solar PV array ($20/kW per year).
[45] Natural Gas O&M: $0.014/kWh. (Siemens estimate).
[46] NREL (projects $0/kWh variable maintenance costs): http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html.
[47] O&M for non-DER microgrid components: $70,000/year (Siemens).

Table 31. Fixed Operating and Maintenance Cost

Table displays estimated values and descriptions of the fixed O&M costs associated with operating and maintaining the microgrid's DERs.

Fixed O&M Costs ($/year)	Cost Components
~ $3,200 (total)	Solar PV System Service Agreements – Annual costs of maintenance and servicing of unit
~ 47,000	Natural Gas Generator Service Agreement – Annual costs of maintenance and servicing of unit
~ $70,000	Non-DER Microgrid Components Service Agreement - Annual costs of maintenance and servicing of components

4.4.4 Distributed Energy Resource Replenishing Fuel Time

The both natural gas units will have a continuous supply of fuel unless the pipeline is damaged or destroyed, therefore the natural gas units will be able to operate continuously. There is effectively no maximum operating duration for the natural gas units in island mode. DERs such as diesel generators have limited tank sizes and have clear maximum operating times in island mode.

The solar PV arrays do not require fuel for operation, but its output depends on weather and time of day.

4.5 Costs to Maintain Service during a Power Outage (Sub Task 4.5)

4.5.1 Backup Generation Cost during a Power Outage

All microgrid generation assets will serve as backup generation in the event of an extended power outage. The proposed natural gas generator will be the most reliable and productive of the DERs, providing an average of 0.3825 MW to the microgrid at any given time. Because the natural gas generator will use natural gas via pipeline as fuel, disruptions to its fuel source are unlikely. The natural gas generator can generate on average 10.8 MWh per day, using approximately 102.6 Mcf (100 MMBTU) of natural gas. The natural gas generator will not require startup or connection costs in order to run during island mode and should not incur any daily variable costs other than fuel.

The solar array will be available for backup generation during a power outage, but its production is too inconsistent for it to qualify as a true backup generator. Extreme weather is responsible for many emergency outages in New York State, and such weather will greatly reduce the output of the solar panels. However, when high state-wide electricity demand on the most irradiated days of summer causes outages, the solar panels will be at their most productive. On average the solar PV array will provide 0.0224 MW of load support to the Watervliet microgrid. Table 32 shows all of the costs associated with operating the DERs during a power outage, including fuel and variable O&M costs.

Table 32. Cost of Generation during a Power Outage

Table lists each generation unit and its respective energy source. Additionally, nameplate capacity, expected power outage operating capacity, and daily average production of power (in MWh) is detailed. Lastly quantity and units of daily fuel and operating costs (both one-time and ongoing) are described.

Location	Distributed Energy Resource	Energy Source	Nameplate Capacity (MW)	Expected Operating Capacity (%)	Avg. Daily Production During Power Outage (MWh/ Day)	Fuel Consumption per Day		One Time Operating Costs ($)	Ongoing Operating Costs per day Fuel and variable O&M
						Quantity	Unit		
Senior Center/Public Library	DER1 – Proposed Natural Gas Generator	Natural Gas	0.45	100%	10.8	100	Mcf	N/A	$500
Senior Center/Public Library	DER2 - Existing Solar Panel	Sun Light	0.03	14%	0.24[48]	N/A	N/A	N/A	$1.64
Fire Station	DER3 - Existing Solar Panel	Sun Light	0.03	14%	0.24	N/A	N/A	N/A	$1.64
Hudson Shores Plaza	DER4 - Proposed Solar Panel	Sun Light	0.1	14%	0.8	N/A	N/A	N/A	$5.48

[48] This output assumes that the PV arrays are still operational after an emergency event. In the case that the PV arrays are damaged, the microgrid will use the natural gas generator as the key source of emergency power.

4.5.2 Cost to Maintain Service during a Power Outage

There are no costs associated with switching the microgrid to island mode during a power outage other than the operational costs already accounted for Table 32. Please refer to Table 32 for one-time and ongoing costs of microgrid generation per day. The proposed microgrid has the capacity to support all the connected facilities, which means even those facilities with backup generation will not have to rely on or pay for on-site backup power. Facilities not connected to the microgrid will experience power outages and may need emergency services depending on the severity of the emergency event. Any other cost incurred during a wide spread power outage will be related to the emergency power (i.e. portable generators) rather than electricity generation costs.

4.6 Services Supported by the Microgrid (Sub Task 4.6)

Most of the facilities to be connected to the microgrid are municipally owned buildings that serve the entirety of the population in Watervliet (such as the police station, fire station, city hall, and public library). Others, like Hudson Shores Plaza, serve a smaller population because they are residential facilities. For estimates of the population served by each critical facility, see Table 33.

Backup power supplied by the microgrid will usually be able to provide 100% of each facility's electricity demand during outage situations. However, if backup power from the microgrid is not available, the critical services provided by these facilities will be severely hampered. Some critical services do not require electricity (e.g. driving a police car to the scene of a crime), while others are completely dependent on a stable power supply (e.g. some municipal buildings or local water sanitizing operations). Based on the portfolio of services that each facility provides and the electricity dependency of each service, Table 33 provides an estimate of how effectively each facility can perform its normal services without electricity.

Table 33. Critical Services Supported

Table details critical services supported by the microgrid during an outage. The table also shows the percentage of services lost for each facility when backup power is not available during an outage.

Facility Name	Population Served by This Facility	Percentage Loss in Service During a Power Outage[49]	
		When Backup Power is Available	When Backup Power is Not Available
Police Station/City Hall	10,250	0%	> 50%
Fire Station	10,250	0%	> 50%
Memorial Recreation Center	10,250	0%	> 50%
Senior Citizen Center/Public Library	10,250	0%	> 75%
Civic Center	10,250	0%	> 50%
Public Works Department	10,250	0%	> 90%
Hudson Shores Plaza	~ 300[50]	0%	> 50%
United Methodist Church	~ 300	0%	> 50%
Residential Group #1	40	0%	> 50%
Residential Group #2	40	0%	> 50%

4.7 Industrial Economics Benefit-Cost Analysis Report

As follows is a direct cost-benefit analysis deliverable from Industrial Economics. IEc was hired by NYSERDA to conduct a benefit-cost analysis of each feasibility study. The benefit-cost analysis of the Watervliet microgrid was delivered to the Project Team on February 25, 2016.

4.7.1 Project Overview

As part of NYSERDA's NY Prize community microgrid competition, the City of Watervliet has proposed development of a microgrid that would serve ten local facilities:

- The Watervliet City Hall and Police Station.
- The Watervliet Fire Station, which provides fire suppression services to the community.[51]
- The Memorial Recreation Center, an indoor facility that offers year-round recreational activities to the community.
- The Watervliet Public Library and Senior Citizen Center.
- The Watervliet Civic Center, an indoor recreation center that serves youth, young adults, and adults in the community.[52]

[49] Booz Allen estimated % loss based on energy demands and services provided for Emergency Services, Municipal Services, Health Services, and Education Services based on previous research by NIH and CDC (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1497795/; http://www.ncbi.nlm.nih.gov/pubmed/15898487; http://emergency.cdc.gov/disasters/poweroutage/needtoknow.asp).
[50] Number of units (http://www.apartmentfinder.com/New-York/Watervliet-Apartments/Hudson-Shores-Plaza-Apartments).
[51] http://www.watervliet.com/city/fire-ems.htm.
[52] http://www.watervlietciviccenter.com/about-us/.

- The Watervliet Public Works Department.
- The Watervliet United Methodist Church.
- The Hudson Shores Plaza, an affordable housing community for seniors with 136 rental units.[53,54]
- Two groups of residences, which for purposes of this analysis will be referred to as "Residential Group # 1" and "Residential Group # 2."

The microgrid would be powered by two new distributed energy resources – a 0.45 MW natural gas unit and a 100 kW photovoltaic array. In addition, the microgrid would incorporate two 30 kW photovoltaic arrays currently installed at the Fire Station and the Public Library and Senior Citizen Center. The city anticipates that all four of these distributed energy resources would produce electricity for the grid during periods of normal operation. The system as designed would have sufficient generating capacity to meet average demand for electricity from the ten facilities during a major outage. Project consultants also indicate that the system would have the capability of providing black start support to the grid.

To assist with completion of the project's NY Prize Phase I feasibility study, IEc conducted a screening-level analysis of the project's potential costs and benefits. This report describes the results of that analysis, which is based on the methodology outlined below.

4.7.2 Methodology and Assumptions

In discussing the economic viability of microgrids, a common understanding of the basic concepts of benefit-cost analysis is essential. Chief among these are the following:

- *Costs* represent the value of resources consumed (or benefits forgone) in the production of a good or service.
- *Benefits* are impacts that have value to a firm, a household, or society in general.
- *Net benefits* are the difference between a project's benefits and costs.

Both costs and benefits must be measured relative to a common *baseline* - for a microgrid, the "without project" scenario - that describes the conditions that would prevail absent a project's development. The benefit cost analysis (BCA) considers only those costs and benefits that are *incremental* to the baseline.

This analysis relies on an Excel-based spreadsheet model developed for NYSERDA to analyze the costs and benefits of developing microgrids in New York State. The model evaluates the economic viability of a microgrid based on the user's specification of project costs, the project's design and operating characteristics, and the facilities and services the project is designed to support. Of note, the model analyzes a discrete operating scenario specified by the user; it does not identify an optimal project design or operating strategy.

[53] http://affordablehousingonline.com/housing-search/New-York/Watervliet/Hudson-Shores-Plaza/24189/.
[54] http://www.rentalhousingdeals.com/NY/WATERVLIET/HUDSON-SHORES-PLAZA.

The BCA model is structured to analyze a project's costs and benefits over a 20-year operating period. The model applies conventional discounting techniques to calculate the present value of costs and benefits, employing an annual discount rate that the user specifies – in this case, seven percent.[55] It also calculates an annualized estimate of costs and benefits based on the anticipated engineering lifespan of the system's equipment. Once a project's cumulative benefits and costs have been adjusted to present values, the model calculates both the project's net benefits and the ratio of project benefits to project costs. The model also calculates the project's internal rate of return, which indicates the discount rate at which the project's costs and benefits would be equal. All monetized results are adjusted for inflation and expressed in 2014 dollars.

With respect to public expenditures, the model's purpose is to ensure that decisions to invest resources in a particular project are cost-effective; i.e., that the benefits of the investment to society will exceed its costs. Accordingly, the model examines impacts from the perspective of society as a whole and does not identify the distribution of costs and benefits among individual stakeholders (e.g., customers, utilities). When facing a choice among investments in multiple projects, the "societal cost test" guides the decision toward the investment that produces the greatest net benefit.

The BCA considers costs and benefits for two scenarios:

Scenario 1: No major power outages over the assumed 20-year operating period (i.e., normal operating conditions only).

Scenario 2: The average annual duration of major power outages required for project benefits to equal costs, if benefits do not exceed costs under Scenario 1.[56]

[55] The seven percent discount rate is consistent with the U.S. Office of Management and Budget's current estimate of the opportunity cost of capital for private investments. One exception to the use of this rate is the calculation of environmental damages. Following the New York Public Service Commission's guidance for benefit-cost analysis, the model relies on temporal projections of the social cost of carbon (SCC), which were developed by the U.S. Environmental Protection Agency using a three percent discount rate, to value CO_2 emissions. As the NYPSC notes, "The SCC is distinguishable from other measures because it operates over a very long time frame, justifying use of a low discount rate specific to its long term effects." The model also uses EPA's temporal projections of social damage values for SO_2, NO_x, and $PM_{2.5}$, and therefore also applies a three percent discount rate to the calculation of damages associated with each of those pollutants. [See: State of New York Public Service Commission. Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision. Order Establishing the Benefit Cost Analysis Framework. January 21, 2016.]

[56] The New York State Department of Public Service (DPS) requires utilities delivering electricity in New York State to collect and regularly submit information regarding electric service interruptions. The reporting system specifies 10 cause categories: major storms; tree contacts; overloads; operating errors; equipment failures; accidents; prearranged interruptions; customers equipment; lightning; and unknown (there are an additional seven cause codes used exclusively for Consolidated Edison's underground network system). Reliability metrics can be calculated in two ways: including all outages, which indicates the actual experience of a utility's customers; and excluding outages caused by major storms, which is more indicative of the frequency and duration of outages within the utility's control. In estimating the reliability benefits of a microgrid, the BCA employs metrics that exclude outages caused by major storms. The BCA classifies outages caused by major storms or other events beyond a utility's control as "major power outages," and evaluates the benefits of avoiding such outages separately.

4.7.3 Results

Table 34 summarizes the estimated net benefits, benefit-cost ratios, and internal rates of return for the scenarios described above. The results indicate that if there were no major power outages over the 20-year period analyzed (Scenario 1), the project's costs would exceed its benefits. In order for the project's benefits to outweigh its costs, the average duration of major outages would need to equal or exceed 12.9 days per year (Scenario 2). The discussion that follows provides additional detail on these findings.

Table 34. BCA Results (Assuming 7 Percent Discount Rate)

Economic Measure	Assumed Average Duration of Major Power Outages	
	Scenario 1: 0 Days/Year	Scenario 2: 12.9 Days/Year
Net Benefits - Present Value	-$3,680,000	$8,340
Benefit-Cost Ratio	0.6	1.0
Internal Rate of Return	NA	7.7%

Scenario 1

Figure 7 and Table 35 present the detailed results of the Scenario 1 analysis.

Figure 7. Present Value Results, Scenario 1

(No Major Power Outages; 7 Percent Discount Rate)

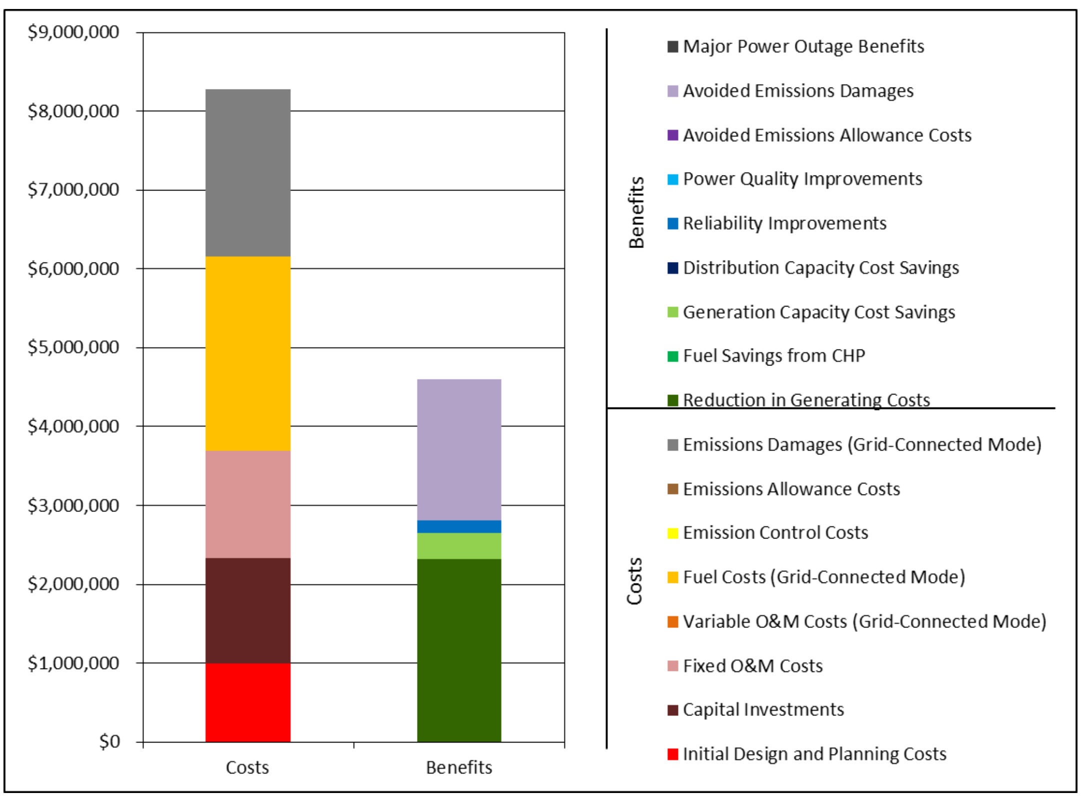

Table 35. Detailed BCA Results, Scenario 1

(No Major Power Outages; 7 Percent Discount Rate)

Cost or Benefit Category	Present Value Over 20 Years (2014$)	Annualized Value (2014$)
Costs		
Initial Design and Planning	$1,000,000	$88,200
Capital Investments	$1,340,000	$114,000
Fixed O&M	$1,360,000	$120,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$2,470,000	$218,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$2,120,000	$138,000
Total Costs	**$8,280,000**	
Benefits		
Reduction in Generating Costs	$2,320,000	$204,000
Fuel Savings from CHP	$0	$0
Generation Capacity Cost Savings	$337,000	$29,700
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$159,000	$14,100
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$1,200	$106
Avoided Emissions Damages	$1,790,000	$117,000
Major Power Outage Benefits	$0	$0
Total Benefits	**$4,600,000**	
Net Benefits	**-$3,680,000**	
Benefit/Cost Ratio	**0.6**	
Internal Rate of Return	**n/a**	

Fixed Costs

The BCA relies on information provided by the Project Team to estimate the fixed costs of developing the microgrid. The Project Team's best estimate of initial design and planning costs is approximately $1.0 million. The present value of the project's capital costs is estimated at approximately $1.3 million, including costs associated with installing a microgrid control system; equipment for the substations that will be used to manage the microgrid; the IT infrastructure (communication cabling) for the microgrid; the new 0.45 MW natural gas unit and 100 kW photovoltaic array; and the power lines needed to distribute the electricity the microgrid would generate. Operation and maintenance of the entire system would be provided under fixed price service contracts, at an estimated annual cost of approximately $120,000. The present value of these O&M costs over a 20-year operating period is approximately $1.4 million.

Variable Costs

The most significant variable cost associated with the proposed project is the cost of natural gas to fuel operation of the system's primary generator. To characterize these costs, the BCA relies on estimates of fuel consumption provided by the Project Team and projections of fuel costs from New York's State Energy Plan (SEP), adjusted to reflect recent market prices.[57] The present value of the project's fuel costs over a 20-year operating period is estimated to be approximately $2.5 million.

The analysis of variable costs also considers the environmental damages associated with pollutant emissions from the distributed energy resources that serve the microgrid, based on the operating scenario and emissions rates provided by the Project Team and the understanding that none of the system's generators would be subject to emissions allowance requirements. In this case, the damages attributable to emissions from the new natural gas generator are estimated at approximately $138,000 annually. The majority of these damages are attributable to the emission of CO_2. Over a 20-year operating period, the present value of emissions damages is estimated at approximately $2.1 million.

Avoided Costs

The development and operation of a microgrid may avoid or reduce a number of costs that otherwise would be incurred. In the case of the City of Watervliet's proposed microgrid, the primary source of cost savings would be a reduction in demand for electricity from bulk energy suppliers, with a resulting reduction in generating costs. The BCA estimates the present value of these savings over a 20-year operating period to be approximately $2.3 million; this estimate assumes the microgrid provides base load power, consistent with the operating profile upon which the analysis is based. The reduction in demand for electricity from bulk energy suppliers would also reduce emissions of CO_2 and particulate matter from these sources, and produce a shift in demand for SO_2 and NO_x emissions allowances. The present value of these benefits is approximately $1.8 million.[58]

In addition to the savings noted above, development of a microgrid could yield cost savings by avoiding or deferring the need to invest in expansion of the conventional grid's energy generation or distribution capacity.[59] Based on standard capacity factors for solar and natural gas

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[57] The model adjusts the State Energy Plan's natural gas and diesel price projections using fuel-specific multipliers that are based on the average commercial natural gas price in New York State in October 2015 (the most recent month for which data were available) and the average West Texas Intermediate price of crude oil in 2015, as reported by the Energy Information Administration. The model applies the same price multiplier in each year of the analysis.

[58] Following the New York Public Service Commission's guidance for benefit-cost analysis, the model values emissions of CO_2 using the social cost of carbon (SCC) developed by the U.S. Environmental Protection Agency. [See: State of New York Public Service Commission. Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision. Order Establishing the Benefit Cost Analysis Framework. January 21, 2016.] Because emissions of SO_2 and NO_x from bulk energy suppliers are capped and subject to emissions allowance requirements in New York, the model values these emissions based on projected allowance prices for each pollutant.

[59] Impacts on transmission capacity are implicitly incorporated into the model's estimates of avoided generation costs and generation capacity cost savings. As estimated by NYISO, generation costs and generating capacity costs vary by location to reflect costs imposed by location-specific transmission constraints.

generators, the Project Team estimates the project's impact on demand for generating capacity to be approximately 0.3965 MW per year (the team estimates no impact on distribution capacity). Based on this figure, the BCA estimates the present value of the project's generating capacity benefits to be approximately $337,000 over a 20-year operating period.

The Project Team has indicated that the proposed microgrid would be designed to provide ancillary services, in the form of black start support, to the New York Independent System Operator. Whether NYISO would select the project to provide these services depends on NYISO's requirements and the ability of the project to provide support at a cost lower than that of alternative sources. Based on discussions with NYISO, it is our understanding that the market for black start support is highly competitive, and that projects of this type would have a relatively small chance of being selected to provide support to the grid. In light of this consideration, the analysis does not attempt to quantify the potential benefits of providing this service.

Reliability Benefits

An additional benefit of the proposed microgrid would be to reduce customers' susceptibility to power outages by enabling a seamless transition from grid-connected mode to islanded mode. The analysis estimates that development of a microgrid would yield reliability benefits of approximately $14,100 per year, with a present value of $159,000 over a 20-year operating period. This estimate is calculated using the U.S. Department of Energy's Interruption Cost Estimate (ICE) Calculator, and is based on the following indicators of the likelihood and average duration of outages in the service area:[60]

System Average Interruption Frequency Index – 0.96 events per year.

Customer Average Interruption Duration Index – 116.4 minutes.[61]

The estimate takes into account the number of small and large commercial or industrial customers the project would serve; the distribution of these customers by economic sector; average annual electricity usage per customer, as provided by the Project Team; and the prevalence of backup generation among these customers. It also takes into account the variable costs of operating existing backup generators, both in the baseline and as an integrated component of a microgrid. Under baseline conditions, the analysis assumes a 15 percent failure rate for backup generators.[62] It assumes that establishment of a microgrid would reduce the rate of failure to near zero.

It is important to note that the analysis of reliability benefits assumes that development of a microgrid would insulate the facilities the project would serve from outages of the type captured in SAIFI and CAIDI values. The distribution network within the microgrid is unlikely to be

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[60] www.icecalculator.com.

[61] The analysis is based on DPS's reported 2014 SAIFI and CAIDI values for National Grid.

[62] http://www.businessweek.com/articles/2012-12-04/how-to-keep-a-generator-running-when-you-lose-power#p1.

wholly invulnerable to such interruptions in service. All else equal, this assumption will lead the BCA to overstate the reliability benefits the project would provide.

Summary

The analysis of Scenario 1 yields a benefit/cost ratio of 0.6; i.e., the estimate of project benefits is approximately 60 percent that of project costs. Accordingly, the analysis moves to Scenario 2, taking into account the potential benefits of a microgrid in mitigating the impact of major power outages.

Scenario 2
Benefits in the Event of a Major Power Outage

As previously noted, the estimate of reliability benefits presented in Scenario 1 does not include the benefits of maintaining service during outages caused by major storm events or other factors generally considered beyond the control of the local utility. These types of outages can affect a broad area and may require an extended period of time to rectify. To estimate the benefits of a microgrid in the event of such outages, the BCA methodology is designed to assess the impact of a total loss of power – including plausible assumptions about the failure of backup generation – on the facilities the microgrid would serve. It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.[63,64]

As noted above, Watervliet's microgrid project would serve ten facilities. The project's consultants indicate that at present, none of the facilities are equipped with a backup generator. Should there be an outage, all of these facilities could maintain operations by bringing in portable generators with sufficient power to maintain all services. Table 36 lists the Project Team's cost estimates for maintaining service with portable generators. In the absence of backup power - i.e., if the backup generator failed and no replacement was available - all of the facilities would experience between 50 and 90 percent loss in service capabilities (see Table 36).

[63] The methodology used to estimate the value of lost services was developed by the Federal Emergency Management Agency (FEMA) for use in administering its Hazard Mitigation Grant Program. See: FEMA Benefit-Cost Analysis Re-Engineering (BCAR): Development of Standard Economic Values, Version 4.0. May 2011.

[64] As with the analysis of reliability benefits, the analysis of major power outage benefits assumes that development of a microgrid would insulate the facilities the project would serve from all outages. The distribution network within the microgrid is unlikely to be wholly invulnerable to service interruptions. All else equal, this will lead the BCA to overstate the benefits the project would provide.

Table 36. Backup Power Costs and Level of Service, Scenario 2

Facility Name	Cost of Maintaining Service with Portable Generator ($/Day)	Percent Loss in Service When Backup Generation is Not Available
Watervliet City Hall and Police Station	$685	50%
Watervliet Fire Station	$610	50%
Memorial Recreation Center	$610	50%
Watervliet Public Library and Senior Citizen Center	$996	75%
Watervliet Civic Center	$127	50%
Watervliet Public Works Department	$526	90%
Watervliet United Methodist Church	$156	50%
Hudson Shores Plaza	$4,589	50%
Residential Group # 1	$610	50%
Residential Group # 2	$610	50%

The information provided above serves as a baseline for evaluating the benefits of developing a microgrid. In addition, the assessment of Scenario 2 assumes that in all cases, the supply of fuel necessary to operate backup generators would be maintained indefinitely, and that at each facility, there is a 15 percent chance that the backup generator would fail.

The economic consequences of a major power outage also depend on the value of the services the facilities of interest provide. The analysis calculates the impact of a loss in the town's police, fire, and electric services using standard FEMA values for the costs of crime, the baseline incidence of crime per capita, and the impact of changes in service effectiveness on crime rates; for response time to structure fires, the ratio of total property losses to direct property losses due to fires, and the ratio of total value of mortality and injuries to total property loss due to fires; and for the economic impact of the loss of electric power on residential customers. The impact of a loss in service at other facilities is based on the following value of service estimates, which were developed using the U.S. Department of Energy's ICE Calculator:

- For the Memorial Recreation Center, a value of approximately $29,000 per day
- For the Watervliet Public Library and Senior Citizen Center, a value of approximately $38,000 per day
- For the Watervliet Civic Center, a value of approximately $13,000 per day
- For the Watervliet Public Works Department, a value of approximately $48,000 per day
- For the Watervliet United Methodist Church, a value of approximately $34,000 per day

Based on these values, the analysis estimates that in the absence of a microgrid, the average cost of an outage for the three facilities is approximately $25,300 per day.

Summary

Figure 8 and Table 37 present the results of the BCA for Scenario 2. The results indicate that the benefits of the proposed project would equal or exceed its costs if the project enabled the facilities it would serve to avoid an average of 12.9 days per year without power. If the average annual duration of the outages the microgrid prevents is less than this figure, its costs are projected to exceed its benefits.

Figure 8. Present Value Results, Scenario 2

(Major Power Outages Averaging 12.9 Days/Year; 7 Percent Discount Rate)

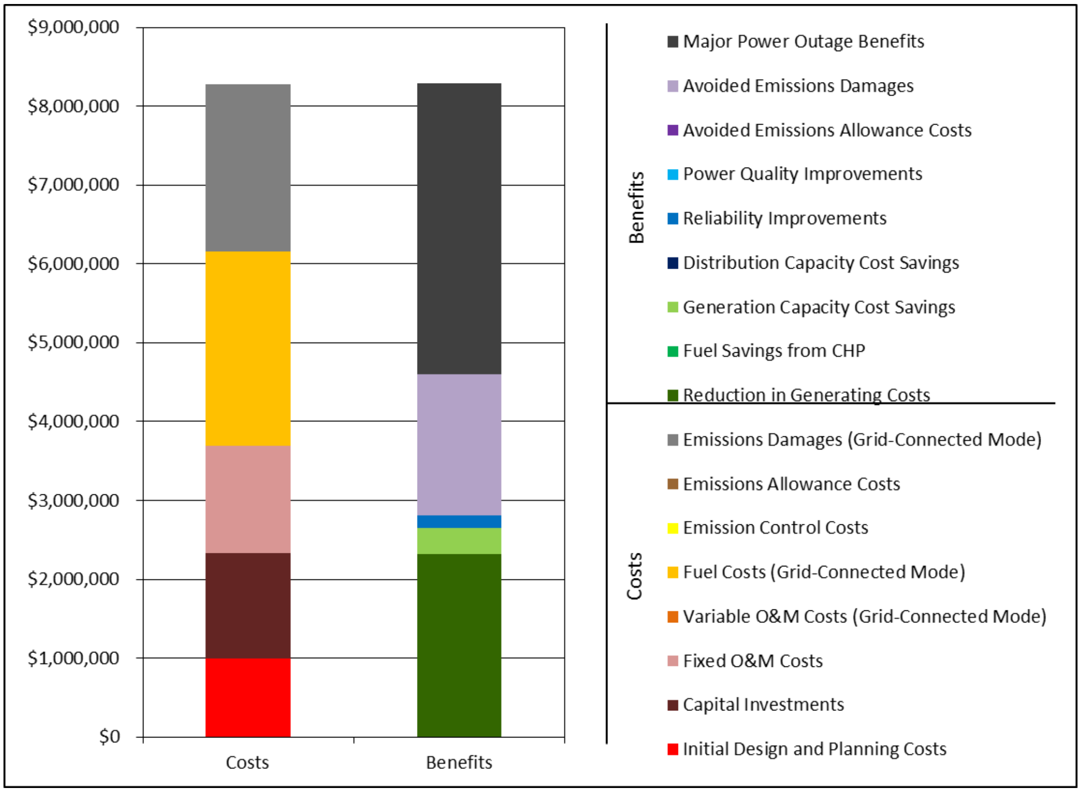

Table 37. Detailed BCA Results, Scenario 2

(Major Power Outages Averaging 12.9 Days/Year; 7 Percent Discount Rate)

Cost or Benefit Category	Present Value Over 20 Years (2014$)	Annualized Value (2014$)
Costs		
Initial Design and Planning	$1,000,000	$88,200
Capital Investments	$1,340,000	$114,000
Fixed O&M	$1,360,000	$120,000
Variable O&M (Grid-Connected Mode)	$0	$0
Fuel (Grid-Connected Mode)	$2,470,000	$218,000
Emission Control	$0	$0
Emissions Allowances	$0	$0
Emissions Damages (Grid-Connected Mode)	$2,120,000	$138,000
Total Costs	**$8,280,000**	
Benefits		
Reduction in Generating Costs	$2,320,000	$204,000
Fuel Savings from CHP	$0	$0
Generation Capacity Cost Savings	$337,000	$29,700
Distribution Capacity Cost Savings	$0	$0
Reliability Improvements	$159,000	$14,100
Power Quality Improvements	$0	$0
Avoided Emissions Allowance Costs	$1,200	$106
Avoided Emissions Damages	$1,790,000	$117,000
Major Power Outage Benefits	$3,680,000	$327,000
Total Benefits	**$8,290,000**	
Net Benefits	**$8,340**	
Benefit/Cost Ratio	**1.0**	
Internal Rate of Return	**7.7%**	

The Project Team assumed an electricity sales price of $0.073 per kWh in Watervliet. This is the supply cost for National Grid, the average amount spent by National Grid to import electricity into their distribution system. On a long term, fixed volume PPA, the Project Team believes this to be the most accurate pricing model. Industrial Economics modeled the location-based marginal price (LBMP) for the local NYISO zone to price electricity sales. The LBMP is effectively the average spot market price, peaking on summer afternoons and dropping to nearly zero in low demand hours. While the LBMP would be an appropriate price for intermittent and unreliable grid sales, the proposal herein supports reliable, continuous electricity injections into the National Grid. In Watervliet, the Capital LBMP is $38.22 per MWh[65], or $0.038 per kWh, a more than 47% reduction in price from the supply cost. The benefits allowed for capacity cost reductions do not bring the electricity prices to parity. This has a predictable influence on the economics of the projects and is the driving force behind the divergent cost benefit analyses developed by the Project Team and by IEc. The Project Team is unaware of any community microgrid business model or generation set that is financially self-sufficient at the LBMP.

[65] Average according to IEc cost-benefit model.

5. Summary and Conclusions

5.1 Lessons Learned and Areas for Improvement

The lessons learned from the Watervliet microgrid feasibility study are divided into two parts. The first part in Section 5.1.1 highlights Watervliet-specific issues to be addressed moving forward. The second part in Sections 5.1.2 and 5.1.3 addresses statewide issues, replicability, and the perspectives of many stakeholder groups. These lessons learned may be generalized and applied across the State and NY Prize communities.

5.1.1 Watervliet Lessons Learned

Through the Watervliet microgrid feasibility study, the Project Team learned site-specific lessons applicable to other communities in its portfolio and around the state.

The loads on the Watervliet microgrid are fairly small, requiring commensurately limited generation to serve the loads during an islanding situation. While the overall costs of the proposal are relatively low, much of the required capital and operating expenditures are tied to the microgrid control systems, the size and cost of which are not scaled to the size of the microgrid. The result is generating assets that can create sufficient revenue to account for their own operating and capital costs, but owing to the small size, do not produce enough excess revenue to pay for the microgrid costs. This is a consideration not only for Watervliet but for many other communities around the state that have smaller loads but still require control infrastructure and software. The upside to the small size is the inexpensive nature of the total project costs, estimated at $1.4 million and one of the least costly projects in the Project Team's portfolio. Low capital requirements, coupled with a dependable revenue stream and the services provided to a low and moderate income community, may support a case for further subsidization of the project as a demonstration microgrid. Future expansion of the grid could include the Watervliet Arsenal with upsized generation to support the new load. While natural gas availability may be an issue, this would allow the microgrid to produce greater operating revenues and return some or all of the capital costs.

The proposal envisions the utility, National Grid, as the owner and operator of the entire project, including the generation assets. While this would appear contrary to the NYPSC ruling that investor-owned-utilities may not own generation, the Project Team believes that the size of the project, only slightly more than one half of a megawatt, and the carve out for exceptions to the prohibition on utility ownership allow this model. In particular, the exception for infrastructure that provides a critical reliability service and would not otherwise be built if not for utility involvement is salient, and National Grid has voiced a willingness to further explore vertically integrated ownership The community in Watervliet may be unable to support rate-based resilience improvements and this project provides an opportunity to improve the local electrical infrastructure with outside support. Any expansion to include the Arsenal would likely necessitate private ownership, as utility ownership of larger generation assets may run afoul of the NYPSC.

In comparison to working with a municipal utility, working with the investor-owned National Grid was a more time-intensive process. As a utility with a large footprint, customer base, and transmission and distribution network, National Grid has many issues to manage that require its attention, among which microgrids and NY Prize were just one. However, National Grid was receptive to the possibility of connecting multiple feeders to create a microgrid design, understanding that there are not sufficient critical facilities on a single feeder. The result is a technically feasible microgrid that meets NYSERDAs critical facility requirements. A NY Prize Phase II award would require more extensive conversations with National Grid about their role in a future microgrid on the proposed footprint and how a microgrid might utilize existing infrastructure absent direct involvement of the utility.

5.1.2 Statewide Replicability and Lessons Learned

Through the process of developing deliverables for multiple communities over several months, the Team has discovered and considered new questions surrounding microgrid development. These questions address technical viability, financial structures, policy considerations, and other constraints that could inhibit the development or expansion of microgrids in New York State.

Technical. The existing electrical and natural gas infrastructure in a community is the chief determinant of what is possible. All of the proposed loads in Watervliet, with the exception of the Fire Station and the Department of Public Works (DPW), are on a single feeder. The Fire Station and DPW are located across the street and require only minimal new distribution lines to connect them to the microgrid. The extent of critical and important facilities on this feeder is unusual, but significantly lessens the complexity and cost of the electrical infrastructure required.

Second, the availability of natural gas infrastructure is a major contributor to positive project feasibility. In communities without natural gas, generation is typically limited to solar PV and the tie in of existing diesel backup generation, given the high costs of storage and biomass and the larger footprints required for wind. Given the intermittency of solar, and the low capacity factor in New York State (approximately 15%), solar installations of a few hundred kW do not provide reliable generation for an islanded microgrid. In contrast, natural gas-fired generation provides a high reliability baseload, is relatively clean and efficient, and allows for cogenerated steam sales if there is a proximate off-taker. Watervliet is fortunate to have natural gas availability, so at the scale of generation proposed, a reciprocating engine is feasible. However, according to National Grid the pressure and volume is variable and sometimes insufficient for larger, more intensive applications. This should not impact the proposed project, however it may be an important consideration if the project were to expand to the Watervliet Arsenal or other large loads that require commensurately larger generation.

Financial. Across the portfolio of communities managed by the Project Team, natural gas availability and steam off-takers are the leading elements of financially viable projects. Simply, natural gas generation is more cost efficient and provides highly reliable revenue streams through electricity sales, and offers steam sales as an added revenue stream that is unavailable to a PV driven system. Given the currently high cost of battery storage options, it is difficult to make a compelling case for a small solar PV-battery system as a reliable baseload option.

Project financial structures are also important to consider. Revenue from these projects is driven almost exclusively by the sale of electricity and, if available, steam; however, the microgrid control components may require a million dollars or more of capital investment. Ownership structures that separate cost drivers from the revenue streams may be difficult propositions, as the microgrid controls owners would have little opportunity to recoup their investment. This is especially true for privately owned microgrids in locations with reliable power supplies where islanding would be infrequent. In these cases, municipal ownership of the generation and infrastructure would be the most effective. The exception is if the entire microgrid can be developed "behind the meter." While it remains to be seen if utilities will allow this to transpire, a fully behind-the-meter solution in an area with moderate to high electricity prices would likely be a more advantageous financial proposition for connected facilities, as well as for generation and controls owners. Moreover, ancillary services have the potential to provide positive revenue for community microgrids; however, they are hard to qualify for because they require high levels of reserve capacity for most programs, and the payments are somewhat small relative to the electricity that could be generated and sold with an at-capacity generator.

Policy. State policy does not currently address microgrids in a cohesive or holistic manner, nor have utility programs adequately recognized microgrid operations in their policies. DR is a potentially lucrative revenue stream in New York; however, current policies do not address microgrid DR participation. For instance, interpretations of the existing NYISO DR programs suggest that microgrids could take payments for islanding in times of high demand on the macrogrid. This scenario, while advantageous from a load shedding perspective, would also remove the microgrid connected generation simultaneously, leaving the macrogrid in a net-neutral position vis-a-vis the microgrid. While the nature of DR payments in such situations is not clear, the Project Team suggests explicit guidance from the New York Public Service Commission (NYPSC) and the various utilities regarding their respective policies. Due to this lack of clarity, DR revenue has generally been excluded from the Project Team's revenue analysis.

The financial viability of many community microgrids would be significantly enhanced if the NYPSC were to include community microgrids as eligible for Qualifying Facility (QF) designation or, absent that change, if the NYPSC were to provide affirmatively lightened regulation[66] for primarily natural-gas fired projects. Qualifying Facilities must meet certain tests regarding generation type and size, distance, and number of users. A behind-the-meter microgrid would provide significantly stronger returns to investors, propel New York State in the direction of a "grid of grids," and provide more opportunities for load support and DR across the state.

[66] CHP, hydro, PV, fuel cells, etc. are already qualifying generation for a QF. Standalone natural gas (turbine or recip.) provides reliable baseload power, and is largely more flexible than the currently included generation types, but is currently excluded. Many locations cannot leverage steam loads and may not have the space available for sufficient PV installations, thus limiting the effectiveness of the QF regulatory status.

This solution would allow generation assets to load follow the facilities within the microgrid, selling power closer to retail rates to the associated facilities, which would result in greater revenues. Excess power may be sold to the utility when the locational-based marginal price (LBMP) is greater than the variable cost of production, and additional revenue may be generated through DR programs participation. While many microgrids may already be eligible for qualifying facility designation, uncertainty about any given project's regulatory disposition drives up costs. The Project Team believes energy costs in New York State, and the current condition of the electricity infrastructure in the State, are ripe for an economically efficient expansion of a system of microgrids. However, this remains an elusive proposition without clarifications in policy.

Lastly, local community involvement is an important contributor to microgrid design success. Though even the most robust community engagement may not overcome highly unfavorable infrastructure, it is nonetheless imperative for steady forward progress. In Watervliet, support from the utility for this effort has been robust and the community has been helpfully engaged. In other communities, as in Watervliet, the Project Team has been in contact with administrators, elected officials, and non-governmental community representatives; this type of engagement is necessary to not only build support among prospective facilities but also to engage on ownership models, generation options, and other considerations that will directly affect the feasibility of the proposal. The engagement and commitment from the community is instrumental to the Project Team's ability to make recommendations that are acceptable and reasonable to the community. In those communities that are more removed from the process it is difficult to make firm recommendations, and the Project Team runs the risk of suggesting solutions that are, for whatever reason, unpalatable to the community.

Scalability. Scalability is governed by three factors. The structure of the electrical infrastructure, defined in the technical lessons learned section above, is a key factor to expansion of the microgrid. At some point of expansion, it becomes necessary to link multiple feeders, and having proximate feeders of the same voltage and connected to desirable facilities is an important criteria. Second, widespread AMI infrastructure makes expansion far less complicated and allows for the selective disconnect of facilities that are not microgrid participants. Watervliet's microgrid is not an AMI remote disconnect based design; however, the utility of AMI is evident in other projects in the Project Team's portfolio. Lastly, the larger the microgrid grows, the more switches and controls are need to be installed, connected, and maintained for smooth islanding and grid-reconnect processes. In the aggregate, such infrastructure is costly and does not provide many direct returns. Utilities are also likely to push back if the microgrid grows to occupy significant portions of their infrastructure. To that end, the Project Team has worked diligently with the local utilities to find acceptable footprints that meet the goals of NYSERDA and respect the operational concerns of the utilities.

5.1.3 Stakeholder Lessons Learned

Developers. Many of the NY Prize project proposals require the Phase III award to achieve positive economics, and several more will remain in the red even with the grant. At this time there is no incentive for developers to participate in the build-out or operation of proposed microgrids that demonstrate negative returns. The potential for developer involvement is highest in communities with relatively high electricity prices and the presence of steam off-takers; these conditions drive project profitability. Moreover, many of the municipalities are interested in part or full ownership of the projects, but either do not have available funds or lose the project economics without the available tax credits and incentives. In these situations, there may be opportunities for developers to leverage the tax benefits through design-build-own-operate arrangements.

Utilities. The Project Team often experienced problems with information flow. The Project Team would request information about feeders, switches, and other infrastructure from the utilities to inform the best possible microgrid design. However, the utilities were often guarded about providing the full data request in the absence of a design proposal, leading to something of a catch-22 in that neither party was able to adequately answer the request of the other without the desired information. These holdups were incrementally resolved to the satisfaction of both the Project Team and the utilities, but gathering data required significantly more time and dialogue than expected. The utilities may have been unprepared for the volume and detail of data requests from the Project Team, and the expected detail of the overall feasibility study may not have been fully communicated to each party.

Investor-owned-utilities in the Project Team's portfolio, including National Grid in Watervliet, were uniformly against allowing a third-party operational control of utility-owned infrastructure. This view is understandable, however it engenders a particularly difficult situation if the utility does not support the microgrid development. In such situations, the microgrid will generally be forced to construct duplicate infrastructure, with is both prohibitively expensive and against the spirit of the NY Prize. In general, utilities which support the integration of their infrastructure to the extent technically possible allow for more expansive microgrid possibilities.

Academics. Academic considerations in microgrid development may center around three areas. First, research into a relatively small grid systems with multiple generators (some spinning, some inverter-based), temporally and spatially variable loads, and multidirectional power flows may inform better designs and more efficient placement of generation and controls relative to loads. The second is optimizing financial structures for collections of distributed energy resources and control infrastructure. To-date, most microgrids in the United Stated have been campus-style developments in which the grid serves a single institution and can be easily segregated from the macrogrid. Community microgrids consisting of multi-party owned facilities and generation are a new concept, and literature on how best to own and operate such developments is not yet robust. Lastly, and related to financial structures, is the idea of how a "grid of grids" would be managed and structured to provide optimal operational support and the right mix of incentives to encourage customer and utility buy-in.

Communities. Engaged communities are important, but so too are realistic expectations of what a microgrid might include. Many communities expected dozens of facilities, or entire towns, to be included in the microgrid without understanding the limitations of the electrical and gas systems, the utility's operation requirements, or simple cost feasibility. While the Project Team worked with each community to scope out and incrementally refine the facilities for inclusion, there is still much work to be done communicating the infrastructural realities of microgrid development. Setting expectations ahead of future microgrid initiatives will help communities begin with more concise and actionable goals for their community microgrids.

NYSERDA. NYSERDA awarded 83 Phase I feasibility studies, providing a wide canvas for jumpstarting microgrid development in the state but also placing administrative burdens on the utilities and on NYSERDA itself. As NYSERDA is aware, the timelines for receiving information from utilities were significantly delayed compared to what was originally intended, and this has impacted the ability of the Project Team to provide deliverables to NYSERDA on the original schedule. As mentioned in the Utilities Lessons Learned above, better communication between the State and the utilities may have preemptively alleviated this bottleneck.

Second, microgrid control infrastructure is expensive, and distributed energy resources require some scale to become revenue positive enough to subsidize the controls. Therefore, many NY Prize project proposals are not financially feasible without the NY Prize and myriad other rebate and incentive programs. In practical terms, this means that, while the NY Prize will create a body of knowledge around the development of community microgrids that did not previously exist, it is unlikely to spur unbridled growth of community microgrids in the State without policy changes. This is especially true in regions with relatively low electricity costs and as well as power supply and reliability problems. This is especially true in regions with relatively low electricity costs. Additionally, many communities that require improvements to the grid for reliability and resiliency and are lower income communities, which creates the added challenge of making them harder to pencil out financially as the community cannot afford to pay extra to ensure reliability. The projects with the least advantageous financials are often those needed most by the community. This gap is not easily bridged without further subsidization from the State.

5.2 Benefits Analysis

This section describes the benefits to stakeholders associated with the project. The microgrid will provide more resilient energy service, lower peaking emissions, ensure critical and important facilities remain operational during grid outages, and support the goals of New York's REV.

5.2.1 Environmental Benefits

New York State's normal energy portfolio is very clean, with primary energy sources being hydropower and nuclear. Therefore, having a microgrid powered by a natural gas-fired reciprocating generator will increase the overall emissions per kilowatt hour (kWh). However, the natural gas generator is cleaner than many peaking assets, which come online when statewide demand is high, and is significantly cleaner than the existing diesel backup at the hospital. The proposed microgrid also offers a platform for expanding renewable generation in the future. The microgrid's generation assets will not exceed current New York State emissions limits for generators of their size and will not need to purchase emissions permits to operate.

5.2.2 Benefits to the City of Watervliet

Critical and important facilities in the City of Watervliet will receive resilient backup power from the proposed generation assets, ensuring they are available in outage situations and reducing the need for further investments in backup generation. The electricity generated with the solar PV arrays and the natural gas-fired reciprocating generator will also offset higher-emission peaking assets during peak demand events and local diesel backup requirements. The Project Team is scheduled to provide a summary of the project analyses and path ahead on March 22, 2016 by phone.

5.2.3 Benefits to Residents in and around Watervliet

Residents of Watervliet and the surrounding community stand to gain from access to a broad range of critical services anytime the microgrid is forced into islanded operation by an outage on the grid. Even if they are not formally connected to the microgrid, all residents of Watervliet and nearby surrounding communities will have access to critical facilities and other important services in the event of an outage. In the future, the microgrid could be expanded to connect more facilities.

5.2.4 Benefits to New York State

New York State will benefit from the continued localization of energy resources, reducing load and congestion on the grid. Moreover, the expansion of distributed energy resources will further the goals of REV and provide a more resilient overall grid. A successful implementation of the Watervliet microgrid will provide a proof of concept for the ownership and operation of a hybrid microgrid with local utility support. In addition, the lessons learned described in Section 5.1 are widely applicable to the further development of REV and future NY Prize efforts into Phase II and III.

5.3 Conclusion and Recommendations

The Project Team has concluded the proposed Watervliet microgrid is feasible. Previous sections have detailed the capabilities of the microgrid, its primary technical design, the commercial, financial, and legal viability of the project, and the costs and benefits of the microgrid. The microgrid meets all of the NYSERDA required capabilities and most of its preferred capabilities.

The main barriers to completion will be obtaining funding for the project's capital costs and constructing new distribution lines needed to connect microgrid facilities. National Grid must also agree to the new interconnection and electrical distribution network because it will incorporate National Grid lines and switches. The Senior Citizen Center/Public Library and Hudson Shores Plaza need to agree to host the proposed reciprocating generator and solar array, and both the Senior Citizen Center/Public Library and Fire Station must allow interconnection of their 30 kW solar arrays. Existing and proposed generation assets and microgrid components must be available for maintenance at all times. The Team is still working with the facilities to ensure that they will allow a third party to service the generation assets and microgrid components located on their land. The Project Team expects these operational challenges to be resolved by the time of construction—these facilities have considerable incentive to support the project, as construction and interconnection will guarantee a reliable power supply and possibly provide distributed energy resource asset owners with new sources of revenue.

The proposed Watervliet microgrid is replicable and scalable, and it provides a proof of concept for a natural gas-driven microgrid in a small community. If successful, it will be a source of new operational information gleaned in operating a true community microgrid within the context of investor owned utility infrastructure and control systems. Improved energy resilience enhances the local population's safety and quality of life during emergency outages, and local energy generation reduces the strain on the larger energy transmission and distribution infrastructure. Future expansion of the microgrid could maintain electric service to more facilities in Watervliet, providing citizens with access to pharmacies, gas, and groceries in outage situations. Moreover, the inclusion of dozens of low and moderate income residences supports state energy goals and the social good.

This microgrid project will also help accelerate New York State's transition from traditional utility models to newer and smarter distributed technologies, and it will help achieve the REV goals of creating an overall more resilient grid, reducing load and congestion, expanding distributed energy resources, reducing GHG emissions, and constructing more renewable resources. It will also encourage citizens within the community to invest and get involved in local energy generation and distribution and will foster greater awareness of these issues.

Finally, the project will demonstrate the widely distributed benefits of microgrids paired with DERs. The utility will see increased revenues and grid performance, the community will reap the positive benefits of living in and around the microgrid, and industrial customers will benefit from the value of avoided outages. For these reasons, the Project Team recommends this project be selected for continued participation in the NYSERDA New York Prize Community Microgrid Competition.

Path Ahead

Moving forward, Watervliet will require capital subsidies to implement the microgrid as proposed. Absent NY Prize Phase III, and potentially additional support, the project will not be financially feasible. However, the City and the utility may use the Feasibility Study as a basis for improving energy resilience and reliability in the community absent a full microgrid implementation. Expanded distributed energy resources within the footprint, even without smart controls and dedicated switches, will add more support for the grid and provide a positive value stream for the owner of the asset. If new assets are small and numerous enough, the net effect may be a footprint that has a wide mix of facilities that can remain online and functioning through an indefinite outage. The expansion of solar in the community, particularly on the many of the available large roofs, need not be tied to a microgrid and if the specific roof orientation and size is advantageous, numerous firms will install PV arrays at no cost to the customer or facility. While this does not create a microgrid, it does stabilize, and often reduce, electricity bills and the benefits of these savings would be magnified in a relatively lower income community such as Watervliet. The expansion of PV in a low and moderate income community, a no-regrets option to help close the energy affordability gap, may be a policy goal that NYSERDA or National Grid desires to pursue.

A significantly larger microgrid footprint may also support a financially viable microgrid. Expanding the bounds of the project would require significant support from National Grid, and the Project Team does not believe that there are electrically proximate critical loads that can be easily added. However, expanding south into the Watervliet Arsenal would likely provide a large and consistent enough load that generation and controls infrastructure would be a cost effective investment. Including a government facility requires a complex set of contract and regulatory actions, but it is not an impossibility. The Project Team did not execute a detailed analysis of the electrical infrastructure at and around the Arsenal, so it remains unclear if the voltages are congruent or what additional effects an expansion may have on the electrical system.

Beyond new DERs in the community, EE is the most cost effective way to bring down energy costs and in the event that a full microgrid is implemented in the future, decreases the required generation associated with it. National Grid and NYSERDA have numerous programs available to customers, ranging from LED upgrade rebates to full energy audits and thousands of dollars of support.

Appendix

Metering data for typical 24-hour load profiles were provided by National Grid. They are included in this feasibility study to show which facilities have highest and lowest load demands at different times of the day. Analyzing these load demand curves has allowed the team to develop a better overall understanding of the generation capacity needed to sustain the microgrid. The Project Team was unable to retrieve *interval* data for National Grid loads, so the team used a simulator to profile typical 24-hour load curves for each facility. The load profiles for all Watervliet facilities are simulated.

REDACTED PER NDA WITH NATIONAL GRID